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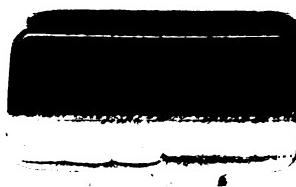
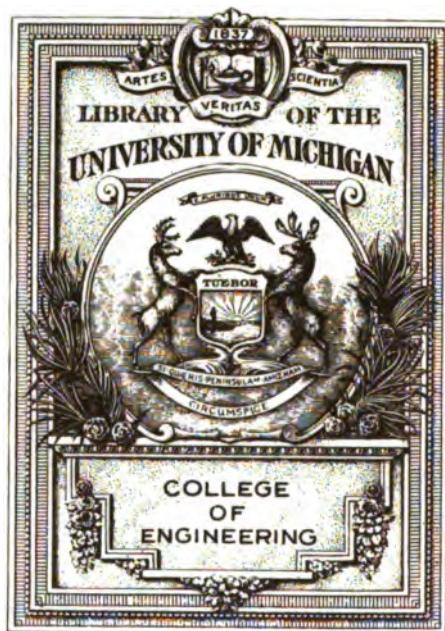
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**CUTTING
CENTRAL STATION COSTS**

CUTTING CENTRAL STATION COSTS

*Ways by which Central Station Managers, Operating
Engineers and Sales Managers are
Meeting High Costs*

COMPILED BY
S. B. WILLIAMS
COMMERCIAL EDITOR, ELECTRICAL WORLD

FIRST EDITION

PUBLISHED BY
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PREFACE

Central stations during the great war met the problems of furnishing energy under heavy restrictions. War brought the necessity of producing power with poor fuels, higher labor costs and extraordinary conditions of demand in many localities.

The central station manager produces electricity to sell. He has always been aggressive in producing power at lower costs and the war has acted as an added incentive to make useful every pound of coal, every piece of machinery and equipment and every dollar of administrative and selling expense.

Practical methods by which scores of central station men the country over have worked out their problems have been compiled in this book. The material has appeared in the *Electrical World* during the last nine months of war. In many cases, one man's idea in one issue has suggested to some other man his plan, which in subsequent issues has been presented for the industry.

The industry now is entering a period of reconstruction and many of the plans and methods which have proved successful have a direct application in the everyday practice of the central station manager.

To make this material most easily available to the reader, the book has been divided into sections—taking up in order operating economies in boiler and generating rooms, line construction and distribution methods and substation practice, then commercial practice and administrative plans, including tried out methods of reducing costs of meter reading, billing collections, the discontinuance of free service and the financing of extensions. The book concludes with timely articles on the training of women in central station work.

This book is essentially a collection of methods. It is presented as a practical help to the men in responsible charge of central station work—a convention on paper to help solve everyday problems.

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CUTTING CENTRAL STATION COSTS

SECTION I

THE BOILER AND ENGINE ROOMS

INCREASING PLANT EFFICIENCY

HIGHER boiler pressures, higher temperatures of superheat, higher vacua, the use of powdered coal, the installation of boiler efficiency instruments and the introduction of bonus systems are six means which an operating engineer in the Middle West considers as most likely to produce important coal savings. Boiler pressures higher than the standard are considered the most important source of saving. While the general impression now is that no saving can be made by going to higher pressures on account of the high cost of the equipment, it is the belief of some engineers that when development charges have been somewhat reduced it will be possible to make high-pressure equipment at less cost than apparatus for 200 lb. (14 kg.) pressure. This opinion is based upon the belief that the boilers for higher pressures will contain smaller tubes, which will give more area with the use of less metal. While the theoretical saving which can be made by the use of higher superheat is small, the actual saving is really greater than the theoretical saving, owing to the fact that the elimination of moisture from the steam throughout a large part of the duty cycle of the steam very largely reduces friction losses. As is well known, many experimenters are working on the problem of powdered coal, and although a number of attempts have been made to promote fraudulent

schemes in this field, a real and legitimate work is being done. Sooner or later it will bring about successful means to release for active work more of the heat units in coal.

The saving which can be made through the use of higher vacua is probably one that demands attention in every plant at the present time. All operators do not thoroughly realize that an increase in the vacuum from 28 in. to 29 in. (71 cm. to 74 cm.) effects a 4 per cent saving on the coal pile, the engineer referred to says. It is usually practicable to make such an increase, although it sometimes entails the installation of better air-pump equipment. Installing boiler-room efficiency instruments and adopting bonus systems should be considered together. They assume increased importance daily as the shortage of power-plant labor becomes more apparent. It is altogether possible that the tendency of the current year will be to employ more intelligent help for the boiler room, even to the partial neglect of the turbine room, so that the investment in boiler-room efficiency instruments and the bonus-paid employees may be capitalized to the fullest extent.

PRACTICAL SUGGESTIONS FOR ECONOMY IN USE OF FUEL

An interesting contribution on the subject of the burning of lower-grade fuels without greatly increasing the boiler-room investment is made by P. B. Juhnke, chief load dispatcher of the Commonwealth Edison Company of Chicago.

The steaming value of a given coal is within certain well-defined limits a function of the size of the coal; likewise, the price of coal is dependent on the size selected, screenings being rated lowest in value. While their test B.t.u. value may be equivalent to that of any given coal, their steaming value in boiler rooms is considerably lower than similar screened coal. However, as screenings will always be a necessary by-product in the coal industry and as 90 per cent of the time they are sufficient, they constitute the logical fuel for central stations.

Burning the lower grade of fuel exclusively, however, requires additional boiler-room equipment over what would be required with the more expensive screened coal for a given steaming capacity. The additional investment required is vitally impor-

tant to central-station companies, whose loads have the familiar sharp peaks, during which time alone the development of maximum capacity is necessary.

A decided step in the direction of economy of both boiler-room investment and high-grade fuel has been made by the Commonwealth Edison Company in its principal generating stations during several peak seasons. The fuel ordinarily burned is not quite sufficient for the development of maximum capacity during the winter evening peaks, and is supplemented in these periods by higher-grade fuel, to permit maximum output. This is done by storing the more suitable coal on the floor and during the peak supplementing the stoker firing of lower-grade fuel by hand firing of the higher-grade fuel in the proportion of approximately fifty-fifty. Such practice permits good combustion of the entire supply and enables the stations to carry their rated full load and more at the most critical time of the daily load, something that would be scarcely possible were the hand firing of high-grade coal not resorted to.

This scheme of developing full load, however, is not altogether free of objections. First, it requires that a large amount of coal be stored on the boiler-room floor, a poor place for coal according to modern conceptions. Second, it requires a large amount of help to store and shovel the coal into the stoker, and this help may be difficult to obtain and is quite expensive.

To overcome these difficulties a scheme has been adopted at the Fisk Street station which has proved quite satisfactory. High-grade coal is kept in one bunker out of every group of sixteen, and the corresponding boiler is kept banked at all times except during peak loads. A traveling bucket movable by a crane is filled from this bunker to supply high-grade fuel to any other hopper requiring it. This arrangement has reduced the labor expense considerably.

Despite the aforesaid difficulties connected with this method of supplementing low-grade with high-grade coal when required, the underlying principle seems good enough to demand special consideration from designers who look to the fuel situation ahead. Provision for auxiliary high-grade coal bunkers that will be large enough to meet the increased demands during peak periods has been made in a few stations, but it might be advisable for all future stations. The capacities of such bunkers need hardly

exceed 5 per cent to 10 per cent of the ordinary bunker capacity. Perhaps one or more central bunkers with chutes to a number of stokers would be desirable, but the method of storing and distributing the coal is mostly a matter of detail arrangement.

It is not difficult to imagine conditions which will give additional economic importance to providing auxiliary bunkers for peak coal, conditions which will affect operating costs as well as investment cost. When they obtain, such an arrangement will recommend itself still more forcibly and is likely to show a decided saving both in the outlay for investment and in operating costs.

To state offhand the saving effected in dollars and cents is somewhat difficult, as location, the price of coal, cost of boiler equipment, and the like, are factors entering into the matter. Outside of the auxiliary coal bunkers, very few other changes will be necessary to adjust the fuel to the load conditions. With such an arrangement one precaution would have to be taken—to prevent waste of the higher grade coal, it being much easier to burn. With hand firing the difficulties connected with burning the higher-grade fuel serve as a good brake against this tendency in human beings to make things as easy for themselves as possible. But even at the worst it would not be a grievous problem for modern types of generating-station executives to solve.

EXPERIENCE WITH PULVERIZED COAL

In an effort to determine the advisability of utilizing pulverized fuel in its plants, the Milwaukee Electric Railway & Light Company early in 1918 decided upon a trial installation at the Oneida Street station. The necessary equipment for preparing and feeding the coal was installed and the boiler was placed in service during the early part of May. From that time until early in August, when the installation was finally proved successful, changes were made to eliminate undesirable conditions encountered during preliminary operation.

Drying and Pulverizing Equipment. The drying and pulverizing equipment, installed in a room near the plant coal bunkers, consists of one 15-ton-per-hour indirect-fired dryer and one 4-ton-per-hour pulverizer. From one of the coal bunkers the fuel as delivered to the plant is carried to the dryer supply

bin by means of a screw conveyor and bucket elevator. From this supply bin the coal is drawn into the drying cylinder by means of another screw. It is carried through the dryer by means of gravity and discharged into an elevator which carries the dried fuel to the pulverizer supply bin. In the dryer the moisture is reduced from 11 per cent to 1 per cent at the rate of about 10 tons per hour.

In passing to the pulverizer supply bin the coal is run over a magnetic separator pulley which removes such iron and steel as has been carried that far. From the bin last mentioned the fuel is fed to the pulverizer through a small screw conveyor on top of the mill. Being driven from the mill shaft by means of a small belt, this screw can be varied in speed through a cone pulley arrangement to allow for the kind of material being powdered.

After passing through the pulverizer the fuel is carried by means of a screw conveyor to the pulverized-fuel storage bin in front of the boiler. All drives on the conveying and pulverizing equipment are so arranged that only such machinery as is in use will be operating.

The equipment for firing the fuel into the furnace consists of a blower and two screws driven by variable-speed motors. The screws, at the base of the powdered coal bin, carry the coal at a uniform rate to the feeder pipes, where it is thoroughly mixed with air by means of agitator wheels attached to the end of the screw shafts. From the paddlewheel the fuel is carried into the furnace by the air blast supplied from the blower. The furnace is of the Dutch-oven type so as to insure the proper flame travel, thus preventing destruction to the brickwork.

When the boiler was first put into operation a number of undesirable conditions resulted. An insufficient air supply caused high furnace temperatures. These temperatures caused fusion of the ash particles and a consequent accumulation of slag between the tubes, on the furnace walls and in the ash pit. The removal of the molten slag presented a rather difficult proposition. It was also found that the combustion chamber was of insufficient size. High gas velocities resulting from insufficient air tended toward destruction of the refractory surfaces of the furnace.

A new furnace was therefore designed. The combustion chamber was enlarged, and a regulated air supply was provided

CUTTING CENTRAL STATION COSTS

for by means of a number of auxiliary air openings equipped with dampers. The accumulation of slag in the pit was prevented by raising the point of admission of the fuel into the furnace. As a result the flame path was raised above the base of the pit; hence particles of ash dropping from the flame are not fused. The ash can therefore be drawn from the pit in the form of a powder and small slugs of slag. Analysis has shown that the ash contains practically no carbon.

Having established satisfactory furnace operating conditions, a series of efficiency and capacity tests were conducted to prove contract guarantees. The brickwork was then given a thorough trial by carrying the boiler at a continuous rating of 180 per cent over a period of several days. A final efficiency test follows:

LOG OF OFFICIAL TEST AT ONEIDA STREET STATION

Heating surface, sq. ft.	4,685
Temperature of feed water (deg. Fahr.), average.....	157.2
Temperature of steam (deg. Fahr.), average.....	448.7
Temperature of flue gases (deg. Fahr.), average.....	495.3
Average boiler pressure	167.0
Fuel (100 per cent bituminous coal) fired per hour, lb.	1990.6
Water apparently evaporated per hour lb.	16,392.0
Water apparently evaporated per lb. of coal, lb.	8.23
Factor of evaporation	1.1502
Water evaporated from and at 212 deg. Fahr., per lb. of coal, lb.	9.47
CO ₂ , per cent average	13.85
O, per cent average	4.38
CO	None
	Average, Per Cent
Fuel Analyses:	
Moisture	10.49
Volatile	35.96
Fixed carbon	49.53
Ash	15.93
Sulphur	2.04
B.t.u., as received	10,779
B.t.u., dry	12,045
Accumulation of slag on tubes	None
Condition of smoke	Light
Heat effect on brick	None
Backlash of flame in burner	None
Lb. steam per hour	16,390.3
Lb. steam per hour from and at 212 deg. Fahr.	18,842.6
Per cent of rating	116.7
Boiler efficiency	85.22
(Flues blown five times during test.)	
Fuel Preparation Deductions:	
Coal used in dryer, lb.	1,140

THE BOILER AND ENGINE ROOMS

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Kilowatt-hour motor operation (449.3), coal equivalent at 3 lb. per kw.-hr.	1,348
Total deduction, lb.	2,488
Resulting net efficiency (per cent)	81
No deduction made for stand-by losses in dryer.	

The boiler is an Edge Moor three-pass water-tube boiler, equipped with a superheater and vertical baffles. The coal feeders and burners are of the "Lopulco" type, manufactured by the Locomotive Pulverized Fuel Company of New York.

Because of the nature of the equipment the coal could not be weighed on the firing floor. To arrive at exact coal figures, it was necessary to run all drying and pulverizing equipment free of coal. The fuel in the pulverized storage bin was run to as low a level as possible and a measurement taken to determine the cubical contents of the powdered coal on hand at the start. Coal for the test run was then weighed into the system at the moist coal bunker. At the close of the run the starting conditions so far as was possible were again established. The samples for analysis, upon which the test results are based, were taken at the moist coal bunker as the coal was weighed in. Moisture samples were also taken at the pulverizer feeder and the burners. All analyses were made at the laboratories of the Milwaukee company.

The feed water used during the test was weighed on the standard tank scales of 2000 lb. (907 kg.) capacity each. All feed-pump gland leakage was accounted for in the way usually adopted on standard boiler tests.

All temperatures and pressures were taken with instruments which previous to the test had been checked against standard instruments. The blow-off piping on the boiler was disconnected so as to insure against any possible loss of water. Flues were blown five times during the twenty-four hours.

Flue gas analyses were determined by means of an Orsat apparatus.

Throughout the test very uniform conditions were maintained. The speed of coal feeders and the drafts carried were held constant. The feed-pump speed had to vary somewhat from time to time. The variation in the rate of evaporation was, however, due to slight changes in the quality of coal during the test run.

Pulverized Coal Versus Mechanical Stokers. 1. Under this

heading fuel-preparation costs will be considered first. In the case of powdered coal this information can be classed under three general divisions:

(a) *The cost of crushing the coal.* This expense is the same for both types of equipment.

(b) *The cost of drying and pulverizing the coal.* Although no cost records are available at present, it is estimated that 32 cents per ton will cover this preparation cost in a 200-ton-per-twenty-four-hour plant using bituminous coal containing about 12 per cent moisture.

(c) *The maintenance cost of the drying and pulverizing plant.* This unit has not been determined from actual experience; however, it is estimated that 3 cents per ton will cover the maintenance. In stoker practice the maintenance cost per ton of fuel fired is close to 5 cents.

Summarizing the above facts, it is evident that, with fuel at \$5 per ton, the gross efficiency shown by the pulverized-fuel boilers will have to exceed that shown by the mechanical-stoker-fired boilers by 6 per cent in order to offset coal preparation costs. A 6 per cent deduction from a gross efficiency of 85 per cent gives a net efficiency of 79 per cent for the powdered coal burner. In stoker practice the maximum attainable gross efficiency at any of the Milwaukee electric plants has been 80.54 per cent. Deducting 2.5 per cent for auxiliary uses, the resulting net efficiency is 78 per cent, which is lower by 1.1 per cent than the figure obtained in pulverized-fuel practice.

Other advantages resulting from the use of pulverized fuel are summarized herewith:

2. Continuous boiler operation at a uniform rating as well as a constant efficiency is made possible. At no time is there a loss in capacity due to the clinkering of coal on the grates or the cleaning of fires.

3. Heavy overloads can be taken on or dropped off in a very brief time through adjustment of the coal feeders and the furnace drafts.

4. From 97 to 98 per cent of the combustible in the coal is utilized, regardless of the quality of the fuel.

5. The ash-handling costs are reduced to a minimum owing to the reduced volume.

6. The banking conditions when operating with pulverized fuel

are somewhat different from those obtained in stoker practice. By stopping the fuel supply and closing up all dampers and auxiliary air inlets a boiler can be held up to pressure for about ten hours. The furnace brickwork, having been heated to incandescence during operation, gives off radiant heat which is absorbed by the boiler rather than sent out through the stack.

The ease of controlling the fuel, feed and drafts, the ability to take on heavy overloads in a brief time, the thorough combustion of the coal and the uniform high efficiency obtainable under normal operation make pulverized coal a most satisfactory form of fuel for central-station uses.

The full story of maintenance expense is only partly known as yet; but indications are that no unusual difficulties will be met. The cost of fuel preparation and labor for operating a boiler room fully equipped with pulverized-coal-burning boilers will be a question for the engineer to decide for himself according to his particular conditions. Properly installed with respect to capacity of storage, size of dryer and pulverizers, and on a sufficient number of boilers properly and fully to employ the minimum number of men, the pulverized-fuel installation will most undoubtedly be more advantageous.

The chief items that must be borne in mind by engineers are the ease with which a high efficiency is obtained and the constant nature of that efficiency as compared with the absence of these advantages in a stoker-fired boiler, unless very closely supervised. There is no doubt that with a well-equipped plant burning pulverized fuel having all the necessary recording and indicating instruments to guide the operators in maintaining the proper conditions, a lower cost of generating steam will be possible than has heretofore been the case with any other style of equipment.

BURNING DUST-BEARING COAL

Several interesting observations on the flow of air through coals were made by L. A. Stenger which have a direct bearing on the important question of fuel conservation in this country. Preliminary tests showed that the weight of air passing through a given coal per unit of time is dependent upon the difference in air pressure through the bed, thickness and area of the bed, state of surface wetness of the coal, and most important, the degree of

fineness of the coal particles. These tests were made with a simple apparatus like a gasometer, which would deliver a volume of air at constant pressure through a cup with screened bottom, which contained the coal under test. The time taken to force the known volume of air through the coal was measured with a stop watch. This furnished data to compute unit air flow.

Different coals of various screen gradings, dust contents, conditions of surface wetness, etc., were tested under comparative conditions. Tests comparing surface, dry, dust-bearing coal with the same coal when the surface was wetted throughout the mass showed that the wet coal allowed approximately twice the air flow that the dry coal would. This is due to the fact that the water collects the small grains, holding them together and to the larger pieces, thus preventing their settling and filling the void spaces. After the coal is again dried, if it is not agitated too much, the dust is cemented together loosely by the deposited soluble salts of the coal. The resulting increase of air flow explains the improvement in combustion of wetted coal. It was

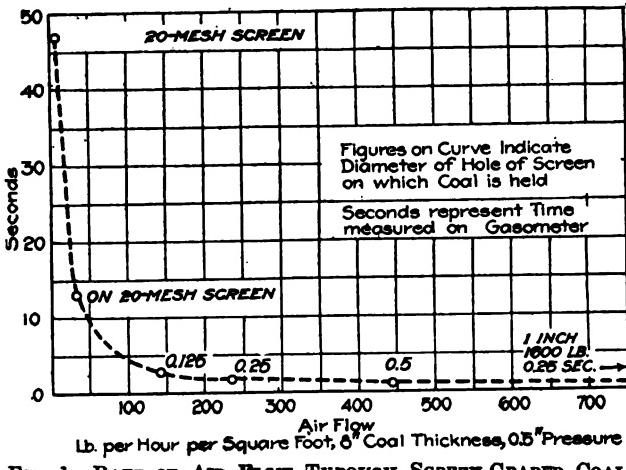


FIG. 1—RATE OF AIR FLOW THROUGH SCREEN-GRADED COALS

also proved that layers of dust, placed either at the top, bottom or in an intermediate position in the coal mass, retarded the air flow to a much greater extent than if the dust were distributed uniformly throughout the coal.

The comparative rates of air flow through screen-graded coals are indicated in Fig. 1. This indicates that air flow was sharply

restricted by grain sizes near $\frac{1}{8}$ -in. (3.175 mm.) and increased at very rapid rates as the grains were larger. That part of coal near $\frac{1}{8}$ -in. grain size and less is designated as dust. The extent to which dust in the coal affects the air flow is shown by Fig. 2. This curve represents the average of air-flow tests on different surface wet coals as received ready for firing.

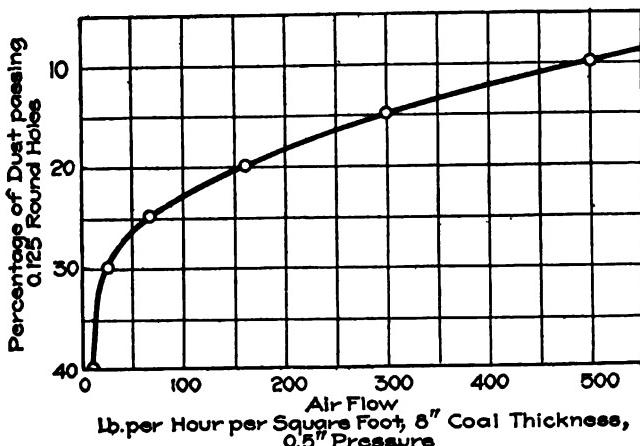
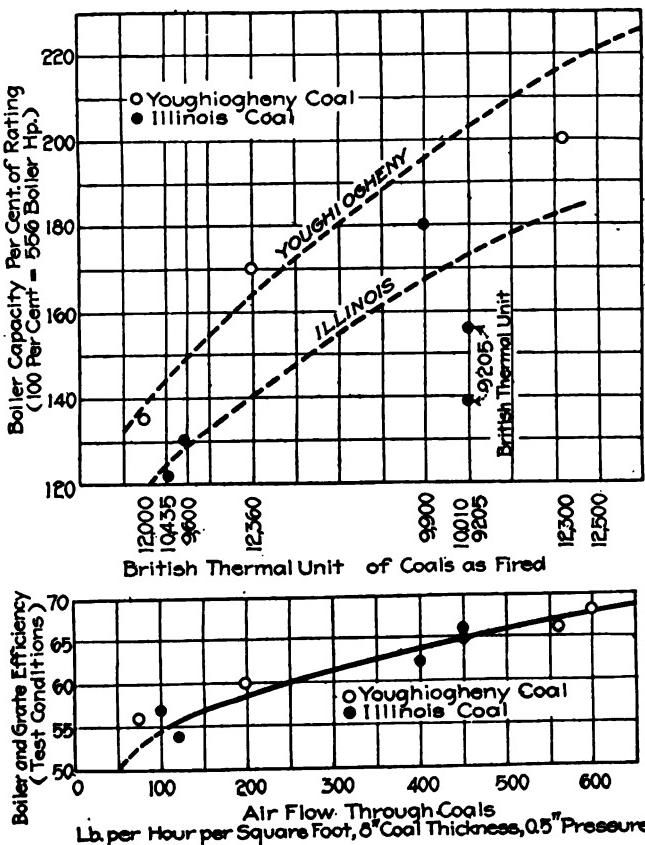


FIG. 2—RATE OF AIR FLOW THROUGH COALS HAVING DIFFERENT DUST CONTENTS

Relation of Air Admittance to Boiler Performance. The relation of air "admittance" of coals to steam-boiler performance is shown in Fig. 3, which gives results obtained from systematic measurements on air flow plotted against data from evaporation tests, with chain grates serving 556 hp. B. & W. boilers. Each of these tests was made with care and attention to details so as to get the best attainable boiler capacity and efficiency. The duration of the tests was from eight to nine hours each. Slack and screenings were used, the largest pieces being not over $1\frac{1}{2}$ -in. (3.81-cm.) in size, usually having wet surfaces as fired and varying in dust content. Some of the tests were made with coal screened approximately dust-free to compare the performance of the coarse fraction with a dust-bearing coal of the same kind. This was done with both Illinois and Youghio-gheny screenings. The B.t.u. value of each of the coals as fired was placed on the chart to show its small comparative influence on boiler performance. A dust-free 9900 B.t.u. coal gave much better results than a dust-bearing 12,000 B.t.u. coal.

It should be understood that the figures representing air flow through cold coal before firing it are no index to the amount of air flowing through the burning fuel bed, but they do show that a coal having limited air admittance cannot be burned efficiently.



Figs. 3 AND 4—RELATION OF MEASURED AIR FLOW TO BOILER PERFORMANCE as ordinarily fired and that there is an important relation between that property of fuels and boiler and furnace performance.

Losses in efficiency due to dust in coal are traced to the difficulty in maintaining a free-burning, uniform fuel bed. Holes, ridges or streaks will form. Air passing through holes and areas of burned-out ash causes augmented chimney losses. Areas of coal impermeable to air lie inert, are only coked, not burned, and finally contribute to losses in the ash pit. Boiler capacity is lim-

ited, owing to low efficiencies and to reduced rates of combustion.

A study of the data presented herewith and other experiences with dust-bearing coals on different types of stokers, including forced-draft stokers and hand-fired furnaces, shows that it is impossible to attain as good results as may be had from dust-free coals of lesser B.t.u. values. There is not much hope that the operating boiler efficiencies ordinarily obtained in large plants can be raised and maintained at any desirable standard if dust-bearing coals are burned with ordinary furnace equipment. To add to the trouble fuel is becoming poorer in all respects and more expensive. Limitation of boiler capacity also contributes to low plant efficiency. This leads to higher costs, both of boiler-house equipment and of operation. Although good types of forced-draft stokers with the ability to increase steam output to 250 or 300 per cent of boiler rating aid much in this regard, their operating efficiency is lowered by dust-bearing fuels.¹

A plan for permanently raising operating boiler efficiency and the boiler capacity of a steam-power plant follows: Crush all coal, if necessary, so the largest lumps will not be over 1 in. (2.54 cm.) in size. Screen on a mesh chosen to remove all dust of $\frac{1}{8}$ -in. (3.175-mm.) size and less. Dry and pulverize the dust and burn in pulverized coal-burning furnaces serving a part of the present boiler installation. The coarse coal may be burned in the remaining furnaces, in which no changes have been made.

The data in the table give comparative estimates on the plan, based on these assumptions: 9600 B.t.u. and 13 per cent moisture in coal as bought; 25 per cent of the dust is screened from coal (dust having 8600 B.t.u. and 15 per cent moisture or 10,000 B.t.u. and 1 per cent moisture as fired); 40 cents per ton of dry dust is the approximate cost of screening all coal and drying and pulverizing the dust, or 9 cents per ton of coal bought. These costs are based on 1917 prices of a pulverizing plant of about

¹ The "operating boiler efficiency" $e = (100 - a) \times b \times c \times 10^{-4}$, where a = the more or less indeterminate losses of the plant, from banking fires, leaks, etc. a varies inversely with the load factor and may be from 5 to 20 in value; b is the operating boiler efficiency, and c is the thermal efficiency of prime movers, including auxiliaries; e is known from $3420 \div$ B.t.u. per kw.-hr. The operating boiler efficiency will always be less than the average boiler and grate efficiency determined from evaporation tests on the same type of fuels used in the plant, and it depends on conditions of fuel, labor and boiler-plant control.

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75 tons daily output and include all the usual fixed and operating charges. It may be noted that the operating boiler efficiency and some other figures set forth for the suggested plan are weighted averages.

COMPARATIVE DATA ON PLAN DESIGNED TO BRING ABOUT INCREASE OF BOILER EFFICIENCY

	With Suggested Plan			
	Present Operation	Coarse Coal	Pulverized Coal	Plant Average
Operating boiler efficiency (per cent)....	55	72	76	73
Calorific value of coal as fired (B.t.u.)..	9600	9900	10,000	9922
Lb. coal as fired per 1000 lb. water evaporated	184	....	....	134
Lb. coal as bought per 1000 lb. water evaporated .....	....	....	....	139
Lb. coal as required per 1000 lb. water evaporated (includes coal for drying dust), total	184	....	....	140
Lb. coal saved .....	....	....	....	44
Coal saved (per cent).....	....	....	....	24
Added cost of coal per ton brought due to treatment .....	....	....	....	\$0.09
Net financial saving (per cent) with coal costing:				
\$1 per ton at plant .....	....	....	....	13.2
\$2 per ton at plant .....	....	....	....	19.7
\$3 per ton at plant .....	....	....	....	21.2
Approximate increase in boiler rating, from 125 to 175 per cent of rating (per cent) .....	....	....	....	40.0

It may be seen that the net saving is based upon the possible increase in boiler operating efficiency only. A further saving is possible in plants with the usual load factor of lighting and power plants by bringing about a decrease of the quantity a in the plant efficiency formula given in the footnote (page 13). This was not estimated on account of the indefiniteness of the figures involved. It would be no inconsiderable economy, owing to less banking of fires, as a smaller number of boilers would have to be fired to carry the peak load than under the conditions previously existing.

With the suggested plan in operation the boiler plant could be better controlled and it would be more flexible and more reliable. There would be much less ash to dispose of. The savings brought

about in money, coal and transportation and the inexpensive increase of power capacity as compared with the previous output would be very helpful at any time.

HIGH-GRADE COAL FIRED DURING PEAK

Influx of war industries coupled with slow deliveries of equipment made the problem of carrying the 1917-18 winter's peak a difficult one for the Moline plant of the Moline-Rock Island Manufacturing Company, which supplies electric service to the "Tri-Cities," Davenport, Rock Island and Moline. Boiler capacity appeared to be the limiting factor. In order, therefore, to obtain the maximum rating out of the existing equipment only high-grade coal was burned during peak hours. Under ordinary conditions Iowa coal was burned.

Getting the high-grade fuel on the fires at the critical time was the chief problem. The difficulty was surmounted by constructing auxiliary bunkers for the high-grade southern Illinois coal. They were constructed of wood and were set almost against the fronts of the 500-hp. boilers in an elevated position so that they could be emptied into the stoker hoppers during peak loads by operating a metal-bound wooden gate. The clearance between these bunkers and the boiler fronts was just sufficient to afford ventilation and to give space for operating levers. The auxiliary bunker in front of each 500-hp. boiler holds 3 tons of coal. Coal was delivered to these auxiliary hoppers by the same machinery that conveyed coal to the overhead bunker that holds the supply of ordinary coal. When the high-grade coal had to be distributed chutes were arranged under the conveyor so that the coal would be dumped into the auxiliary bunkers instead of the main bunker. With underfeed stokers it was possible to get as much as 300 per cent of rating out of the boilers with this arrangement, but with the chain-grate stokers 175 per cent of boiler rating was about the limit that could be obtained.

At the Fort Dodge (Iowa) Gas & Electric Company, which is under the same management as the Davenport company, the same idea was utilized in a different way and for a different purpose. In constructing the plant permanent arrangements were made to

fire two kinds of coal in order to reduce the investment which would otherwise be necessary for additional steaming equipment. The boiler plant at Fort Dodge consists of 500-hp. boilers with a sectionalized 17-ton bunker divided into two equal parts. One part is for Iowa coal and one is for southern Illinois coal. Duplicate spouts are provided to each stoker hopper. During the peak, or at times when transmission line failure places extra load on the plant, it is possible to get at least 20 per cent increase in rating over the best that can be obtained with Iowa coal. It may be possible to get even better performance. The great saving in this instance comes, however, from the saving of investment in one entire boiler equipment, which would amount to around \$22,000.

UNIFORM FUEL BED ESSENTIAL

A fuel bed that is not of uniform thickness, condition and porosity cannot be productive of the highest efficiency. The condition of the fuel bed is often made worse by the excessive and unintelligent use of slice bars and pokers for the purpose of keeping up steam pressure. This results in several losses: (a) It makes the fuel bed uneven in thickness or distribution, causing holes, with resultant loss due to excessive air; (b) stirring up the fuel bed generally causes much smoke and soot, which lowers the heat-absorbing capacity of the plant by forming a coating on the boiler and economizer heating surfaces and results in a greater heat loss in the flue gases; (c) stirring up the half-consumed coal and coke brings the ash to the top of the fuel bed, where it fuses and runs together, making clinkers. This action renders part of the grate surface ineffective by closing off the passage of air.

FUEL ECONOMY WITH BONUS SYSTEM

One of the objections commonly raised by engineers who do not wish to establish a bonus system in the boiler room is that it tends to encourage dishonesty by the firemen. They contend that under such a system the men must be trusted to weigh coal and report all readings and that there is a tendency on their part to "juggle" the figures so that the bonus will be secured regardless of the real economy obtained.

However, if the bonus is based on the weight of coal at the mine and on the kilowatt-hours delivered to the switchboard, this objection is obviated, according to a company in the West which operates an 11,700-hp. boiler room.

The men in this plant are provided with everything needed to assist in operating it efficiently. A permanent steam leak is a thing unknown. As soon as it appears a man is on the job fixing it, because in every free steam jet he sees his bonus escaping. Although the plant burns lignite, it has been possible since this system was installed to get an average economy of about 2.9 lb. of fuel per kilowatt-hour. It also keeps the men interested in the operation of the plant and creates a better feeling.

PREVENTING FURNACE EXPLOSIONS

Probably every one who has operated boilers has at some time encountered the furnace explosion that blows fire doors open and singes the fireman's hair with the hot flame or blows coal particles into his face or eyes. The incident is not uncommon and, although potentially a dangerous occurrence, fortunately in most cases causes only temporary disability. The use of so-called low-grade fuels at this time of coal scarcity and high prices for marketable coal tends to increase the seriousness of furnace explosions. A brief discussion of their cause and prevention, based on the experience of Gilbert Rutherford may therefore be of value.

Furnace explosions happen either when the furnace door is opened or when it is closed. The reason for the explosion is the same in both cases, but the manner in which the explosion is brought about is different in the two cases.

Consider an instance where a furnace is incased in a setting that is new and airtight so that air infiltration is eliminated by plastering up cracks and crevices, etc. No air enters above the fuel bed, and the furnace chamber is filled with combustible gases. The fire doors are closed and the furnace is operating, and at fairly low rate of combustion, which means comparatively high draft for a thick fuel bed. The fireman now opens the fire door to throw on some more coal or to look at the fire or to rake it over. There being a difference of pressure between the inside and the outside of the furnace chamber, such that the air rushes

from the outside to the inside, the air from the boiler room is caused to rush in immediately and mix with the combustible gases above the fire. Combustion occurs instantly and with such rapidity that it has an explosive effect, blowing out the gas and coal into the face of the fireman. The simplest remedy is to maintain balanced pressures, or nearly so, between the inside and outside of the furnace chamber.

Another common cause of explosion is in cases where the furnace doors are closed after being opened. Suppose a fireman throws a shovelful of slack coal—for example, anthracite dust—upon the fire. To prevent cooling the fires he opens the door wide, throws in the coal as quickly as possible and shuts the door again immediately. While the fire door is open the furnace settings fill with air, partially at least. The slack coal thrown on the fire spreads over the fuel bed and combustible gases are distilled. The gases rising from the fire may contain as much as 30 per cent of combustible. This mixes with the air entrained in the settling, the mixture becomes ignited, a small explosion occurs, and the firedoor of the furnace is blown open with considerable force as a consequence.

The banked fire may constitute a danger in several ways, a danger that can be largely removed by remembering that it is possible and taking the simple precautions which follow. The cause is evidently that virtually all air supply to a banked fire is shut off so that the distilled gases do not have an opportunity to burn. As a result, if the proper quantity of air is accidentally admitted a violent explosion is liable to occur. To prevent the dangers of an explosion from this cause it is important to shut the furnace and ash-pit dampers sufficiently to prevent air passing through the fuel bed any faster than is required to keep the fire alive; close the flue damper as much as possible without impeding the escape of the gases distilled by the banked fire and allow air to enter the furnace above the fuel bed. By maintaining air circulation above the fuel bed and through the flue damper stagnant explosive mixtures if formed are able to escape. To prevent explosions occurring when opening the bank preparatory to bringing the fire back to active operation the flue damper should be opened some time before closing the air inlet over the fire. Then, after the combustible gases have had accelerated cir-

culation, it is safe to open the fire dampers, and later the firedoor, to start up the fire again.

The crux of the matter of furnace explosions is the control of the air. The air required for complete combustion, which means highest combustion efficiencies, is different from that required for explosion. Maintenance of approximately equal pressures outside and inside of the furnace, which is accomplished easily where the balanced-draft system of automatic control is employed, tends to accomplish this automatically. However, care should always be exercised to safeguard the furnace and the firemen, and the need for this is greater where coal dust and coals of small particles are used.

BOILER-ROOM MANAGEMENT PLAN

The best practice for making a fireman is to select a young man and teach him the job, it was pointed out by T. N. Wynne, Vice-President and Chief Engineer of the Indianapolis Light & Heat Company, before the Indiana Electric Light Association. This course of instruction should last at least two years, and his time should be divided between operating and repairing. By repairing grates and stokers and cleaning and repairing boilers the student fireman familiarizes himself with the apparatus he is to operate and hence can fire with much greater intelligence. Too much time or pains cannot be taken with a man who is to handle the company's coal.

The fireman must be intelligent and honest—intelligent so that he can understand his instruments, and honest so that he will not make these instruments lie. In the average plant the fireman is turned loose on the coal pile and his job is to keep up steam. Usually there is no reference made as to how he is to do this, since he is supposed to have completed his education in the dim past and to require no further instruction. Experience has shown that the average fireman must be watched very closely or he will do extremely wasteful things. As a general rule, especially in inclined-stoker or hand-fired plants, the fireman will fire and sit down, fire and sit down, and follow this plan throughout the watch. He will try to make his periods of sitting down last as long as possible by firing heavy and then letting the steam drop as far as he dares. He then starts a new cycle. The

remedy for this is not to allow the fireman to sit down at all. This is made possible by having the fireman stand eight-hour watches and allowing no chairs or benches in the boiler room. This is not a hardship to the fireman. When he knows he is not supposed to sit down, he interests himself in his work and forgets about quitting time. This results in better and steadier fires and higher economy.

A fireman should not be allowed or required to do any other work than attend to his fires. It is the practice in some plants to require the fireman to look after pumps, heaters, etc. This of course is practical in a very small plant, but in larger plants it is decidedly not so. It gives the fireman an excuse for poor fire regulation. He cannot be blamed for having a wasteful fire if he is at that moment packing a pump.

A certain number of instruments are absolutely necessary in order to determine the degree of economy being obtained by the

FIG. 4A—COMPLETE BOILER-PLANT RECORD

boiler and grate. A boiler and grate has a maximum efficiency at a certain rating. This rating should be found by an actual boiler test. This point of greatest economy is usually around 160 per cent of boiler rating. This rating should be maintained continuously, except of course in cases where it is necessary to

crowd the boiler, as at peak load. This is where the underfeed stoker has the advantage over the other types. It can be operated during off-peak hours at the point of highest efficiency and crowded, as has been demonstrated, to 400 per cent of rating during peak hours. Operating at 400 per cent is decidedly uneconomical, but it is no more so than carrying banked boilers. The instrument to give this information regarding rating is the steam-flow meter. This instrument is the most essential of all the appliances of the boiler room.

The B.t.u., ash, sulphur and moisture must be determined for the coal being burned. Increase in ash and moisture decreases the B.t.u. and consequently increases the freight bill and maintenance cost per thousand B.t.u. Whenever there is a coal shortage it is next to impossible to get the desired quality of coal, but no let-up should be made in the demand for the best coal available. Sulphur affects the rating which can be obtained from grates, especially of the inclined type, but it is not an appreciable factor on chain grates or certain kinds of underfeed equipment.

Necessarily a calorimeter and some sort of coal-weighing apparatus should be used. A sample of coal should be taken from each car so that the entire car will be represented in the sample. A car sample should weigh about 1000 lb. (453 kg.). This sample should be handled in the manner laid out by the American Society of Mechanical Engineers. The weighing of the coal and ash can be done on scales suited to the purpose of the particular plant.

Special pains must be taken at all times with the fire. At normal loads a thin, fast fire is probably the best. With a thin fire holes are more apt to occur than in a thicker one. Hence the thin fire needs more attention, and this may account for the fact that the thicker fire predominates. A draft gage will tell the condition of the fire better than anything else and eliminates opening the inspection door so often to look at the fire. Opening the inspection door means a momentary cooling of the gases. When the first boiler test is made the draft over the fire necessary for different thicknesses of fire and boiler ratings can be determined. These values can be plotted so that for any rating the thickness of fire is known, as well as the draft necessary and, in the case of stokers, the stoker speed.

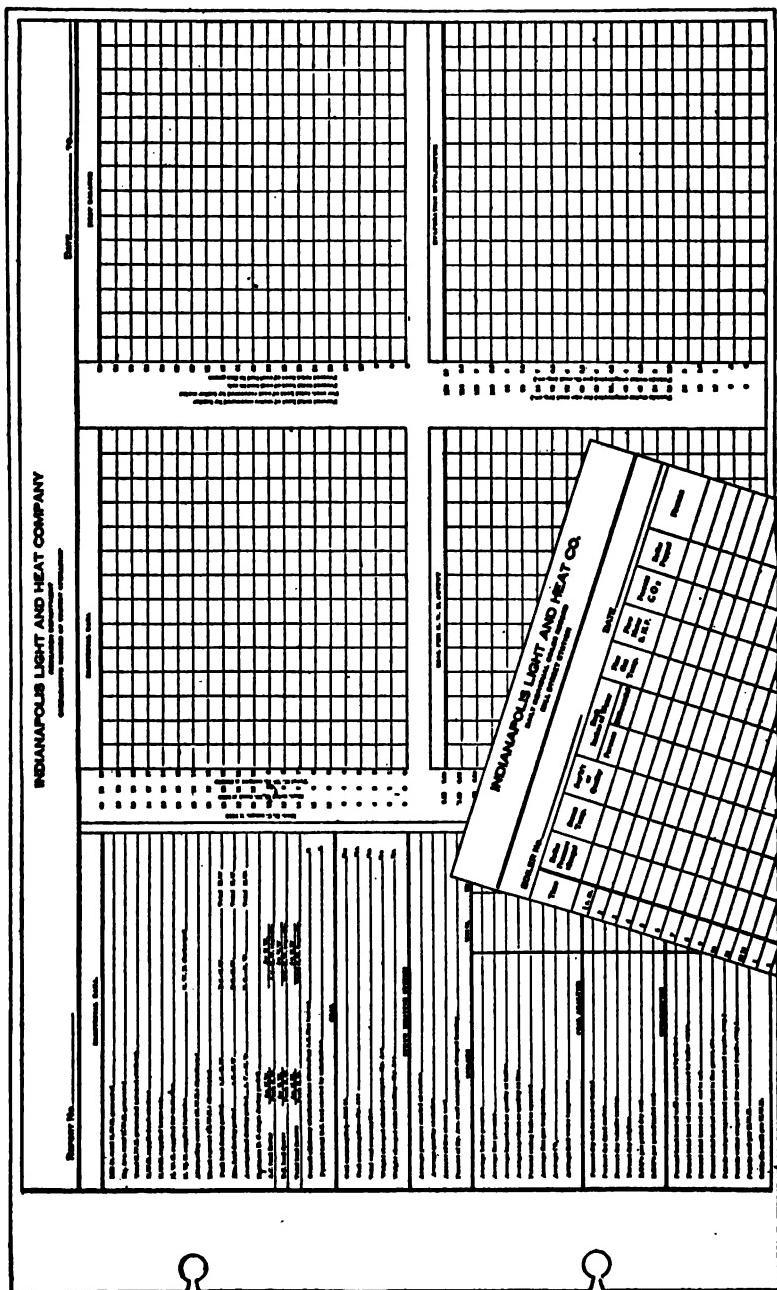


FIG. 6—COMPARATIVE RECORD OF STATION OPERATION AND DAILY INDIVIDUAL BOILER RECORD

Two draft-gage connections should be made—one over the fire and another at the damper or base of the stack. The latter shows the amount of draft available at all times. Other connections can and should be made in case a thorough watch is to be kept on the boilers. These connections should be in the ash pit and ahead of each baffle opening. These will keep a check on the places of greatest resistance within the boiler setting and will show if any of the openings are becoming stopped up.

The temperature of the outlet gases from the boiler setting to the stack is a good indication of whether or not the boiler is clean. If the tubes are covered with soot and scale, the water will not absorb so much heat as otherwise. Soot is a good insulator and scale is not very far behind it. Soot can and should be removed at least every twelve hours by means of mechanical soot blowers, supplemented by a hand steam lance, for the soot blowers may not remove all the soot, and as a rule they do not, especially on superheated tubes. If soot is allowed to remain, it will soon become a very high insulator.

The flue-gas temperature should be as near the final heat of the steam as possible. As long as the temperature of the flue-gas remains constant the boiler is clean, but as soon as the temperature begins to rise one of three things or all can be looked for—soot, scale or leaky baffles. Pyrometers are made so that one instrument may be used on any number of boilers, up to and including twelve, each boiler having its own thermocouple and leads back to the instrument.

Carbon dioxide, or CO_2 , indicates the condition of the fire and the combustion of the gases. In a sense it is the ratio of the air used to the air that has not been used. If, in a test for CO_2 , CO , or carbon monoxide, is obtained, it will be on account of one of the following reasons: insufficient air supply, improper furnace design, improper method of firing, too low a furnace temperature so that the gases are too cold to ignite, poor mixing of air and combustible gases, or poor selection of fuel. For the average Indiana coal and the amount of air required to burn it, 12 per cent CO_2 is a good figure. Low CO_2 is caused by an excess of air, insufficient air (which would cause high CO) or improper mixture of air and gases. However, the most common fault is excess air, and in many cases this is caused by a leaky setting.

All settings should be plastered with one of the boiler-coating preparations on the market.

Measurement of CO₂ is important. A drop from 16 per cent to 10 per cent CO₂ means a waste of fuel of 5 per cent, while a drop from 10 per cent to 6 per cent CO₂ means 12 per cent loss of fuel, and a drop from 6 per cent to 2 per cent means 57 per cent loss of fuel. So there should be added to our list of instruments a CO₂ recorder. If it can be a continuous chart recorder, so much the better, but if it is a hand apparatus, let the sample of gas be taken when the fireman is not looking.

The instruments mentioned constitute those which are necessary for good economy in a boiler room. They should be bought and used honestly. Whenever they give the information that there is any improper condition inside the boiler setting, this condition should be remedied as soon as possible. The instruments should be calibrated and taken care of so that they will perform efficient service. If they are not taken care of, they are worse than useless, for they will lie. This list may be supplemented by others which are important but not absolutely necessary, such as the furnace temperature pyrometer, a coal sample grinder, apparatus for determining sulphur content, CO recorder, etc. It would be poor business to obtain certain results from day to day from these instruments without properly recording these results for future reference.

A form should be provided for daily boiler operation, and this form should include all readings of any value. The readings for each boiler should be taken simultaneously as often as conditions dictate. Care should be taken that the fireman does not allow his fire to drop down between readings.

Another form should be used for the heater and still another for the coal and ash. The heater form should show the inlet and outlet water temperature and the amount of water used. The coal and ash forms should show the weight of coal used and the weight of ash for a twenty-four-hour run. It should also show the kind of coal, where it is from, and how much is on the way. The amount of storage coal should be shown on the same sheet.

Another form to use is the maintenance form—one that includes the repairs made on boilers, stoker, brickwork and auxiliaries. This information will not only apprise the chief engineer of the repairs being made but will also give boiler hours on the

THE BOILER AND ENGINE ROOMS

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INDIANAPOLIS LIGHT AND HEAT CO. DAILY REPORT OF GROSS LOADS												
REPORT NO.	MILL STREET STATION			KENTUCKY AVENUE STATION			WATER TOWER			SUB-STATION		
	Hour	Min.	Sec.	Hour	Min.	Sec.	Hour	Min.	Sec.	Hour	Min.	Sec.
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122	00	00	00	122	00	00</						

FIG. 6—DAILY REPORT OF OPERATIONS AND HEATER REPORT

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equipment. It is a good thing to know how long a stoker can operate without entire replacement or which grade of firebrick lasted the longest under the same conditions. These results should, by all means, be consulted by the purchasing agent, since they not only give absolute data on the life of material but also allow him to anticipate his needs.

All these reports, together with those from other parts of the station, are collected at a certain time and consolidated into one station daily report. The best time for collecting these reports is midnight. From then until morning a clerk can consolidate the information and have the daily report ready for whoever desires it in the morning.

Thus the manager or chief engineer may look over this report for an hour in the morning and tell exactly how the station was operated for the previous twenty-four hours. He can tell what mistakes were made in operating, what apparatus needs attention, or the effect of changes made a day or two before.

A monthly report and a yearly report should be compiled. The monthly report gives the average results for a month and compares the month in question with the eleven preceding months. Such information as pounds of coal per kilowatt-hour, B.t.u. per kilowatt-hour load, pounds of water evaporated per pound of coal, etc., is contained in the report. These comparisons should be made in curves. The same outline applies for the yearly report.

Reports should not include useless information or too much detail. Be sure what readings or computations are desired, that these readings be taken and the computations made for every report. Also see that the final reports are looked over every day by the chief engineer and that he follows out whatever suggestions he receives from them. If this system is not followed out, it is obvious that the whole thing is useless, but if it is followed out, big dividends may be expected.

It may seem at first as if all this equipment will cost a prohibitive amount of money. There is no question that it will cost some money, but the investment is gilt-edged. The Indianapolis (Ind.) Light & Heat Company realized \$50,000 saving the first year this system was put into force, and with coal and material prices as they were the income from this investment in 1918 ran over \$100,000.

BONUS SYSTEM FOR COAL SAVING

To improve the operating economy of a power plant is not a task that can be accomplished over night. Neither can gratifying results be obtained without first clearly defining the aims and plans for the improvement campaign or without the executives or operating officials securing the co-operation of the plant employees. The first thing to do, according to Walter N. Polakov, Consulting Engineer, New York City, is to place the equipment in first-class operating condition. Second, the maintenance work must be organized so that inspections and overhauling of apparatus will be conducted on a schedule frequent enough to forestall damage and prevent deterioration of efficiency.

The next step will be to investigate thoroughly each unit of equipment and determine by tests its maximum inherent efficiency. Inasmuch as the results are affected by the conditions under which they are obtained, the latter should be carefully noted. When this is done the study and test researches should be conducted on a larger scale in order to establish the relations of conditions governing the operation of individual units on the all-around total plant efficiency. Inasmuch as the final aim is not the highest thermodynamic efficiency but the best operating economy, the preceding findings should finally be modified in order to determine and standardize such conditions, supplies, methods, etc., as would necessarily produce the desired result. In determining the final aims the following aspects should not be lost sight of: Best service to the community, welfare of employees, safety of all concerned, and cost of operation, maintenance, idleness and standby losses.

When this part of the work is done, and not before, can the actual task setting for firemen, engineers, switchboard operators, etc., be considered, as it is evident that with poor upkeep of equipment, unstandardized supplies and methods the operating men cannot maintain the prescribed conditions.

Shifting Responsibility to Employee. Many easygoing owners and managers of plants, realizing that the actual performance is falling short of that possible, often shift the responsibility from their shoulders to those of the employee by offering a premium for performance which is sufficiently better than the present, leaving it to the employee to secure the "better results."

In such cases the management sidesteps its duty in not saying *how* the better results can be accomplished and *what* they shall be. Such methods are sometimes advocated as giving the employee freedom to develop his ingenuity. This sophistry is easily exploded when it is considered that the operating man seldom has time for investigation and researches. His hands are full keeping the wheels turning. Furthermore, measuring and indicating instruments and devices are often lacking. The peculiar requirements of a research man—highly developed power of abstraction and observation, ability to concentrate on one problem to the exclusion of all others—are faculties which are seldom, if ever, found in men engaged in routine operating work.

Many Bonus Plans Unsatisfactory. It is generally conceded that higher efficiency warrants higher compensation and that stimulation for efficient work is necessary for its perpetuation. However, the lack of careful study of the subject is responsible for many misconceptions. Most of the methods of extra compensation are unsuitable, yet no better plan can be adopted unless the principles and operating conditions are properly organized. The faulty methods may be classified as follows: (a) Profit-sharing plans; (b) premium schemes, and (c) rewarding individual efforts.

Profit Sharing.—Profit sharing is based on the assumption that the employees by their work contribute to the success of the enterprise in securing profits. This would be entirely correct if the employees had the opportunity to control all functions of management, fix the salaries of directors and direct purchases and sales, besides having a veto in financial transactions. As long as they are expected, however, to work under the conditions provided by the management, with equipment and material furnished by the management, which in turn disposes of the product, the profit or loss is only slightly influenced by the excellence of the work done by the men. If dividends are not declared, the workmen lose their share, perhaps through no fault of their own, since even if they have been working as hard as possible, blunders in policy and mismanagement will offset any good they have done.

Premium Plans.—Premium plans, as worked out in power plants, are very unsatisfactory. The common error of all the attempts in this line is that the final cost of operation is consid-

ered as a basis for the award or denial of the premiums. Yet it is perfectly clear that the cost depends not only on the excellence of work but equally, if not in a much larger degree, upon the method and means of upkeep, cost of fuel and supply and its quality, quantity of output, load factor, use factor, etc. None of these factors is under the control of the power-plant employee. Besides, the extent to which different employees contribute to

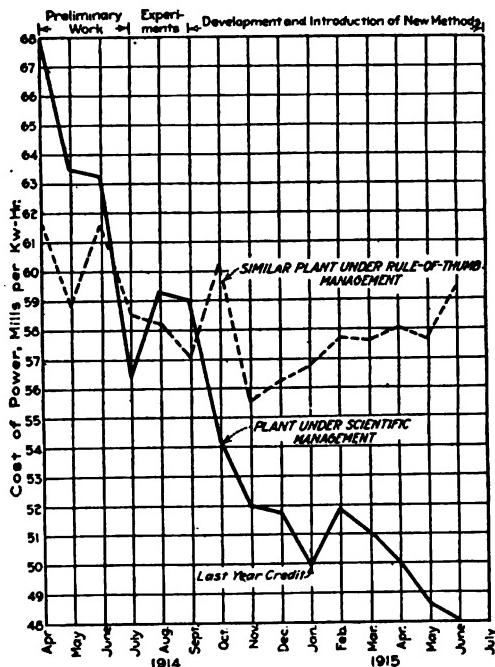


FIG. 7—COMPARISONS OF RESULTS SECURED IN PLANTS RUN BY RULE-OF-THUMB AND BY SCIENTIFIC METHODS

the attainment of economical results is very unequal. While the firemen may effect as much as 50 per cent saving, the switchboard operator cannot influence more than, say, 5 per cent, whereas the floor engineer can save or waste about 1.5 per cent at the most.

The unsuitability of the premium plan was forcefully demonstrated several years ago in a plant where employees who had been accustomed to earning premiums were unable to do so any longer owing to the use of poorer coal and a reduction in load.

Rewarding Individual Effort.—The rewarding of individual

effort is perhaps the most unscientific scheme of all. The same objection exists that was cited before—the responsibility for securing better results is shifted onto men who have no authority to alter the conditions under which they are expected to produce results. The common error in applying the reward is to select arbitrarily one or more isolated factors, like CO₂ in flue gas, carbon in ashes, etc., and reward men obtaining the best results. It is generally overlooked that any one or several of these factors do not indicate the true performance of the whole process. It is often wise to lose in one direction in order to gain more in the final result. Moreover, it is absurd to request men to secure better results without teaching them how to do it and without providing them with instruments showing the progress made.

If one of the advocates of these short cuts would take pains to investigate any of his hobbies—whether high CO₂, or low flue temperature, or good ashes, or anything else that can be produced—he would find that the relation of the factors is complex enough to warrant detailed study. Furthermore, good results cannot be expected unless the equipment used is maintained in first-class operating condition and the supplies furnished are the most suitable and of uniform quality.

A glaring example of inconsistency of the individual-reward plan is offered by the experiences of a Western railroad. Here it was recognized that the actual performance was worse than that possible, and that local conditions of various plants called for different standards.

The work of establishing standards of performance was based not on actual experiments but on average statistical data of the past, reduced by the guessed percentage suspected as waste. Then an allotment was made for each individual plant as to how much fuel should reasonably be consumed there per month. Similarly, pay rolls were revised and certain labor costs were assumed as reasonable. These two records multiplied by constants arbitrarily chosen (6 for fuel and 4 for labor) added together and divided by 10 gave the figure of merit used as a basis for the payment of bonus, the bonus itself being adjusted on a sliding scale.

The shortcomings of this crude method are apparent:

1. Men are left to discover for themselves how to secure the results desired by the management.

2. The management, shifting the responsibility to the men, was uncertain as to the exact amount of saving accomplished due to individual efforts, and therefore could not fix a definite bonus.

Task-Setting Plan That Brings Results. As opposed to all these methods, Mr. Polakov advocates the assignment of a well-defined task to each member of an organization. The setting of a task presupposes the complete and detailed knowledge of each and every process performed in the plant and includes reliable information as to what each unit of equipment can do and what are the conditions producing the desired results. This knowledge, once gained through test and research work, is made available by instructions and training. Results necessarily follow conditions; therefore the task really consists in maintaining conditions as prescribed, not in attaining results, inasmuch as they are assured if all requirements are complied with.

To determine whether the men live up to their instructions, and consequently whether they earn their bonus, it is often convenient to judge by final results. However, these are not necessarily definite indications, since results may fall short of pre-determination because of conditions beyond the control of the employee. To illustrate: Boiler efficiency may materially drop through no fault of the fireman if baffles and arches in the boilers are not maintained, owing to poor planning, lack of material, etc. Steam consumption may increase above what it should be if cool condensing water is not available. The man may fail to remove the ashes in the prescribed time if the locomotive batteries are not properly charged, the cleaning schedule disorganized, etc. It would be obviously wrong to deny the bonus to the employee who did all that was expected of him but who was unable to produce results through the fault of somebody else or something that could not be prevented by him.

Under such conditions an investigation should be made, not to verify the results, but to find out whether the conditions prescribed by the instruction card were lived up to. If they were, that is all that was expected from the employee and his bonus should be allowed him. This basic principle should apply in all cases. Favorable conditions may produce results slightly better than specified, yet they do not call for any additional reward since they evidently are not due to any extra work on the part of the employee. In other words, the bonus remains constant as

long as the terms of the instruction card are complied with, irrespective of whether the results are equal to, above or below a certain predetermined value. In case results are below a specified mark the bonus should be paid in full or not paid at all, depending on the investigation previously mentioned, but never should the bonus be reduced.

TABLE I—TWO TYPICAL REPORTS SHOWING INCREASE OF EFFICIENCY FROM ADOPTION OF METHODS OUTLINED IN TEXT

	CASE I	
	Representative Week 1917 (Nov. 17, 1917)	Corresponding Week 1916 (Nov. 18, 1916)
Total coal used, lb.	441,280	506,240
Coal equivalent in shavings, lb.	31,350	38,450
Total fuel used, lb.	472,630	544,690
Total water evaporated, lb.	4,901,170	4,625,250
Actual evaporation, lb. per hr.	10.37	8.51
Average steam pressure	58	56
Average feed temperature, deg. Fahr.	170	168
Factor of evaporation	1.073	1.075
Equivalent evaporation from and at 212 deg. Fahr., lb. per lb. coal	11.12	9.15
Average B.t.u. per lb. coal	14,800	13,550
Boiler efficiency, per cent....	72.9	65.6

	CASE II	
	Representative Week 1917 (Nov. 24, 1917)	Corresponding Week 1916 (Nov. 25, 1916)
Total coal used, lb.	452,480	526,400
Coal equivalent in shavings, lb.	29,700	40,350
Total fuel used, lb.	482,180	566,750
Total water evaporated, lb.	5,045,800	4,837,800
Actual evaporation, lb. per hr.	10.45	8.55
Average steam pressure	58	57
Average feed temperature, deg. Fahr.	163	176
Factor of evaporation	1.081	1.067
Equivalent evaporation from and at 212 deg. Fahr., lb. per lb. coal	11.30	9.12
Average B.t.u. per lb. coal	14,800	13,550
Boiler efficiency, per cent....	74.0	65.4

The knowledge of how to do things properly and the strongest desire to work according to the best methods are of no avail unless the conditions are such that it is possible to apply these qualifications. It is a well-known fact that the daily performance in a plant operating under old-fashioned management falls short of the results obtained during a specially arranged test.

This is due chiefly to the failure to plan the work ahead and permanently maintain the conditions prevailing during the test.

In considering conditions which should be maintained to secure the best economy the elimination of causes producing fatigue should be given first rank, as in power-plant work neither the best of machinery nor excellent supplies can produce satisfactory results unless they are handled by men who are not tired, mentally or physically. From experiments conducted with firemen it has been found that, other conditions being equal, a fireman on a twelve-hour watch is about 4.5 per cent less efficient than the same man on an eight-hour shift.

No one familiar with the common layout of a power plant can over-emphasize the importance of hygienic conditions to enable men to live up to their task day in and day out. While engine rooms not infrequently offer very pleasant and sanitary surroundings, boiler-houses, the most important part of any plant, are often so built as to make them unbearably cold in winter and uncomfortably hot during the summer. Good lighting is so unusual that after looking into the furnace a fireman can seldom read the gages or examine anything around the boiler. Good drinking water is rarely provided. If provided with restful seats having backs the firemen can clean the fires twice as rapidly as without them.

The absence of elementary conditions of comfort in a working place where the men spend the greater part of their lives is more harmful to the employers than to the employees. Petty annoyances and feelings of discomfort divert the attention of the men from the performance of their duties to means of avoiding the annoyance. Steady attention on the part of the firemen is much more important than is generally realized.

Of no less importance is the hygienic surrounding on the switchboard gallery. Flickering light from lamps on a low-frequency circuit, glare on the glass fronts of instruments, cement floors to walk on, inconveniently located telephones or telautographs, too low log desks, etc., are all excellent means to increase steam consumption per kilowatt-hour and reduce the safety to men, property and service.

It should be at least as much the duty of a management periodically to investigate and test the effect of surroundings on the attentiveness and physical fatigue of men as it is its duty to test

coal deliveries and supervise the treatment which equipment receives. There are many ways to ascertain the degree and the character of fatigue, but reference thereto will not be made here for lack of space. Whatever the methods may be, they should be applied at regular intervals to each and every employee, and their individual health-record cards should be kept, using some convenient rating to watch easily the decline or gain of vitality of each man. Should the decline be noticed, measures should be taken at once to find out the cause. If it is of individual nature, good advice or doctor's services should be offered. If it affects a group, the harmful condition must be eliminated as rapidly as possible. Little alterations that are usually required to remove harmful conditions are a great deal cheaper (not to say humane) than breaking in and training a new employee, or even a temporary substitute.

TABLE II—IMPROVEMENT IN PENNSYLVANIA PLANT BY SETTING TASK WORK AND GIVING BONUSES

BOILER ROOM			
Coal used (banking excluded), lb.....	48,800	49,200	34,000
Water evaporated, lb.....	419,800	408,200	284,000
Actual evaporation, lb. per hr.....	8.62	8.32	8.37
Factor of evaporation	1.2187	1.2185	1.2287
Equivalent evaporation, lb. per lb. coal.....	10.50	10.13	19.28
Efficiency of generation, per cent.....	73.4	70.8	71.8
Cost of fuel per 1000 lb. of steam, dollars.....	0.0815	0.0845	0.0833
ENGINE ROOM			
Hydroelectric output, kw.-hr.....	980	850	30
Steam generated output, kw-hr.....	21,220	20,450	15,070
Load factor, per cent.....	79.5	64.4	67.5
Steam per kilowatt-hour, lb.....	19.78	20.00	18.85
Coal per kilowatt-hour, lb.....	2.30	2.40	2.26
Thermal efficiency of plant, per cent.....	10.71	10.27	10.73

To conclude this rather condensed outline of the principles advocated by Mr. Polakov, it might be of interest briefly to review a few typical cases where this mode of management has been adopted. Several years ago he was asked to specify additional boiler equipment in a plant containing ten Manning boilers equipped with Jones underfeed stokers. To-day the old plant satisfies the 30 per cent increased demand, using only seven of the old boilers, and the efficiency, which had been slightly below 50 per cent, is now about 73 per cent. No investment of any kind

for generating equipment was made, but about \$2,000 worth of instruments was provided, which yields 400 per cent interest. After the instruments were provided and the efficiency raised from 50 to 65 per cent by stopping various leaks, further progress was made by training employees in maintaining high boiler efficiency.

In a Pennsylvania public utility company, where the average efficiency as established by an eighty-day observation of hand-fired Edge-Moor boilers was 54 per cent, without any expense for replacement of generating equipment and with only a few additional instruments, the described methods, comprising the task work with bonus, improved the average daily performance, as exemplified in Table II, about 33 per cent.

The adoption of the same principles in a 32,000-kw. central station, even without paying bonuses, resulted in the improvement of operating economy as represented graphically in Fig. 7, showing how operating cost was reduced about 30 per cent. The dotted line on the chart represents the result of operation of a competing plant in similar service in the same time.

HOW BEST TO EDUCATE POWER-PLANT OPERATORS

Experience leads the Toledo (Ohio) Railways & Light Company to believe, it was said by W. E. East before the Ohio Electric Light Association, that the best way to educate power-plant operators is to make arrangements to let them conduct their own educational work. It is believed best to have meetings at the plant when the men are off duty and to pay the men for the time thus occupied if necessary to secure full attendance. The classes should be run on a club basis. It has been learned that if a group of men from the "front office" try to initiate a movement for the benefit of the plant men the whole plan will be viewed with suspicion. So educational work must proceed from the inside out, not from the outside in. The part of the company's officials and department heads in this work should be to make the operators feel the need of educational activities and then to let them take it up among themselves, helping them, of course, if they desire help, but never trying to force assistance upon them.

It is also believed that such abstract studies as arithmetic,

physics, electricity and mechanical drawing have no place in these meetings. Men who wish to take such subjects will avail themselves of other opportunities to learn them. The real province of the power-plant club is to take up problems of ordinary operation. Questions arise daily as to the best methods of operating stokers, boilers, condensers, etc. At a weekly get-together meeting the club can handle these topics. A fireman, for example, may have ideas of his own, based on his experience, as to how to operate his stokers. The boss may have told him to run his stokers in a way that seems quite wrong, but if he is the right sort of a fireman he will be willing to learn that he is wrong through discussion in the weekly meetings.

Meetings appear to be most successful when the program includes discussion and study of only one piece of apparatus. A good plan is to have some one previously appointed to give a description of the apparatus illustrated with blueprints and catalogs. A question box should be established and used. If manufacturers' rules pertaining to operation of the apparatus are available, they should be read. Then the meeting should be thrown open for discussion by every one from the ashman to the boss. Material and literature from manufacturers should be preserved to form a reference library for the club.

Employees of the Toledo company have such a club. It is known as the Water Street Boiler-Room Club, because its membership consists of practically every boiler-room operator at the Water Street generating station. Mr. Washburn, the boiler-room fireman, was instrumental in organizing it, and the men have supported it enthusiastically, electing him president. All suggestions are acted on by the club before the reports of those suggestions which seem worth while are submitted by the club president to the superintendent of production. The club, in general, works along the lines discussed above, although it also engages in some social activities. While the club is still young, successful results thus far indicate that it will serve to promote general welfare of the men and the company.

Other Correlated Activities Also Important. In addition to the boiler-room club, the employees and the Toledo company participate in other educational activities. One of these is the joint section of four national engineering societies, the National Electric Light Association, the American Gas Institution, the Amer-

ican Electric Railway Association and the National District Heating Association. The joint section was organized for the educational improvement of its members and to foster good fellowship through social events. It has conducted a number of weekly evening classes in arithmetic, algebra, electricity and mechanical drawing. Day classes have sometimes been held for night shifts. The company has paid for instructors and furnished the meeting room. The classes have been conducted on the same principle as classes in grade schools. On the whole, the work has been successful in teaching general subjects, and the joint section is largely responsible for other educational work which has since been started. As a further means of providing men with opportunities for general education the company pays three-fourths of the cost of a correspondence-school course if an employee completes the course.

Another plan that was used for a time to teach practical topics was the "station-operating class." As a part of this plan a course of study was laid out and speakers were assigned various topics as follows:

Introductory meeting; outline and discussion of work planned; fuels and combustion; furnaces and stokers; boilers; coal and ash handling system; draft systems, natural and mechanical; feed-water purifiers and heaters; superheaters, steam piping and auxiliaries; testing and measuring apparatus, and description of the Acme power station, East Toledo.

A number of these talks were illustrated. This class was well attended and considerable interest was aroused. The class was considered in that respect very successful. However, in another way this class was not successful in that it did not reach the large body of men it was intended to interest. The men who should have been present, the plant operators, were not there in a sufficiently large proportion, and the ones that were present would not partake in the discussion. In fact, most of the operators who came did not seem to feel at home and failed to get into the game as it was hoped they would.

Personal training is also being given to the firemen in connection with combustion tests which are run by the results department. These tests are made for the double purpose of checking up the accuracy of the boiler-flow meters, draft-gage settings, etc., and also to enable the firemen to become familiar with the

use of these instruments. The man who is running the tests and the fireman get together, and the tester tells the fireman that he wants to get the fire as hot as possible. He then shows the fireman what his boilers are doing, provided the boilers are equipped with meters, and they set out to improve conditions, if possible. Readings are taken of draft, boiler output, air flow, analysis of flue gases, stack temperature, etc., and the fireman is informed of all these readings as they are taken. Then as conditions are improved the results are pointed out to the fireman and he is shown how his boiler meter will guide him in his every-day operation of the fires and enable him to obtain the best results at all times. As an incentive to the fireman to make good records, methods calculated to inspire rivalry are pursued.

At the Water Street station the company also has a fireman's instructor, whose duties are to break in all new firemen and to teach them to make full use of all the boiler instruments. This man also supervises all the fires on all special tests and in that way keeps in touch with all the testing work which is carried on in the boiler room.

In conclusion, the company believes that much good can be done in an educational way along all three lines; that is, general work, which takes up the fundamental subjects; the special classes, which include the operators' clubs, and the personal work, which is intended to give individual instruction. However, it is believed that the most successful endeavor and the one most profitable to the company is the operators' club. From experience that appears to be the best place to start. After this club is in full operation the demand for the more academic classes will become greater and the personal work will become easier and will accomplish more.

METHOD FOR MAINTAINING PLANT EFFICIENCY

Because of the efficiency measured in kilowatt-hours at switch board per unit of fuel oil used varies with the temperature of the condenser circulating water, the Houston (Tex.) Lighting & Power Company was obliged to find some method of comparison for informing the station engineer whether or not he was operating the plant to obtain the best results. The water is obtained from a bayou which is a sluggish stream and which becomes very

warm during the summer months. The variation in efficiency is a function of the circulating water and, according to Frank G. Frost, general superintendent of the company, the summer and winter loads have been very carefully analyzed to get average

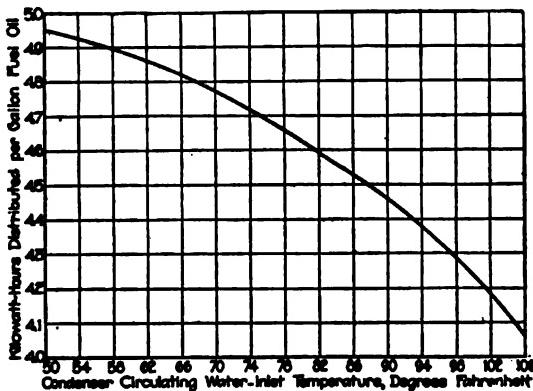


FIG. 8—CURVE OF POWER-PLANT EFFICIENCY USED AS STANDARD

values. From the steam curve of the turbines a "bogie" curve, as seen in Fig. 8, has been worked out which gives the relation between the station outputs with variable circulating-water temperatures. The percentage that each day's results are above or below this curve is posted in the station turbine room so that the operators at all times are familiar with the actual economies of the station. Fuel-oil and electric meters are read hourly.

RESULTS OBTAINED BY USE OF FUEL-OIL REGULATOR

The Houston Electric Company of Houston, Tex., has installed in its plant a device for automatically regulating the amount of fuel oil fed to the furnaces under its boilers. The regulator is arranged to operate with the increasing and decreasing load. In fact, the device is more than merely a fuel regulator. It is an automatic draft, fuel oil and injector-steam regulator which absolutely controls the three essentials to boiler operation when crude oil is used for fuel.

When a sudden load is placed on the main generator of the plant it will naturally cause a drop in the main steam-pressure line. This causes a drop in the steam line which is used for

spraying the oil over the grate, as steam for this purpose is obtained through a reducing valve from the main line. This reduction in pressure causes the regulator to function. When this regulator acts, it performs three duties simultaneously: First, it supplies more fuel oil to the grates; second, a greater quantity of steam is released to cause the oil to spray properly, and, third, the draft over the fire is increased. These three operations make the steam come quickly up to standard practice.

The point at which the regulator will function has been selected by adjusting it according to the steam pressure desired and also taking into the account the CO₂ record produced by a Hayes automatic CO₂ recorder. This recorder is interconnected so that it can be used to take readings from any of the four boilers in the boiler room.

An average of the oil consumed from November, 1916, to August, 1917, showed that the plant used 2.1169 lb. of oil per kilowatt-hour. During September, October and November, 1917, since the CO₂ recorder and the automatic regulator have been placed in service, the oil consumption has amounted to 2.010 lb. per kilowatt-hour. These figures show that the automatic operation has effected a saving of 0.1009 lb. of oil per kilowatt-hour. This indicates a saving of 4.95 per cent in the amount of fuel used. Since the company's fuel bill in the average month is \$3,735, it may be seen that the saving effected is 4.95 per cent of \$3,735, or \$184. Since the automatic devices cost only \$390, it will be seen that one will virtually pay for itself at the end of two months.

SAVE COAL BY WATCHING RADIATION LOSSES

Loss of heat from uncovered or poorly covered steam piping or equipment is more important, Austen Bolam points out, than it seems on first thought, because the boiler and furnace efficiency must be taken into account. In other words, if condensation occurs it means that the equivalent loss is equal to the superheat plus the latent heat divided by the efficiency. If the condensate is not drained back into the boiler, the heat required to raise the water to the boiling point is also lost. If the efficiency of steam generation is low, say 50 per cent, it means that the actual loss is really twice the apparent loss.

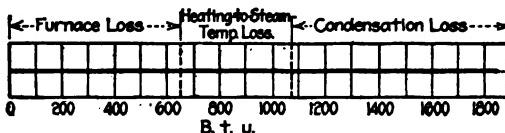


FIG. 9—COMPONENTS OF TOTAL LOSS RESULTING FROM UNCOVERED PIPES THROUGH CONDENSATION OF 1 LB. OF STEAM AT 150 LB. PRESSURE

Many steam plants have their main steam lines covered with insulation of some kind, but it is a very common practice to omit the coverings on valves, flanges, drips, feed pipes and other minor fittings, often because of a fancied difficulty in providing easily removable coverings. They are also great heat wasters, however. The amount of heat, for instance, wasted by one pair of uncovered 10-in. (25.4-cm.) flanges will probably amount to a ton of coal a year. Removable covers are easily made with a little fine chickenwire and some canvas, burlap or muslin, covered with plastic insulating material. They can be made in halves or sections and held in place by wire wrapping. Boiler tops, ends, drums, breechings and walls all need proper insulation. In the latter instance it will protect against air infiltration as well as from heat loss. A thickness of from 2 in. to 3 in. (5.1 cm. to 7.6 cm.) of covering is the least that should be used.

Writing¹ several years ago, Professor MacMillan said: "The saving due to the use of proper covering is so great that . . . the cost per year rather than the first cost should be the only consid-

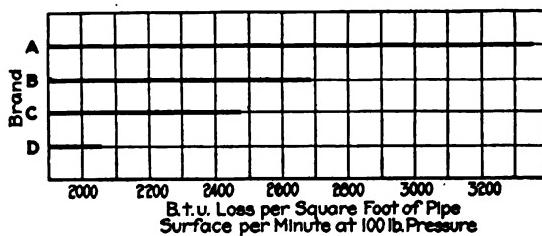


FIG. 10—RELATIVE EFFICIENCIES OF FOUR BRANDS OF PIPE COVERING

eration." In another place he said: "It is a deplorable fact that few steam lines at the present time are provided with thick enough coverings for the greatest net saving." Conditions have not changed appreciably since then, as lack of knowledge regard-

¹ *Proceedings A. S. M. E.*, December, 1915.

ing the insulating values of different substances and the extensive amount of guessing at the thickness of covering required indicate. Coal consumption is responsible for from 55 per cent to 75 per cent of the total operating expense of the average power plant or central station. Therefore economizing in any portion of this enormous consumption is well worth the effort.

Fallacy of Rule-of-Thumb Methods. In some cases engineers have decided on the thickness of pipe covering to use by feeling the covering after one thickness has been applied. If too hot, another layer is applied, and so on. Rule-of-thumb methods like this should be abandoned, since no two hands sense temperature alike and the hand can bear a temperature of 150 deg. Fahr. (65.60 C.) without discomfort. To illustrate the loss which can occur if only the touch test is applied for determining insulation efficiency suppose the steam pressure is 100 lb. (7 kg.). The temperature of the steam, without superheat, would be 327 deg. Fahr. (163.9 C.), so that with a temperature as high as 150 deg. at the outside surface of the covering the loss would be 40 per cent of the initial heat in the steam, most of it preventable by a covering of sufficient thickness.

Unfortunately there is extensive misinformation regarding the

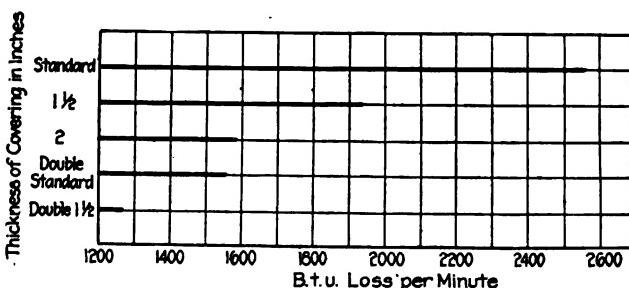


FIG. 11—RELATIVE LOSSES WITH DIFFERENT THICKNESSES OF COVERING
Temperature different between air and steam, 300 deg. Fahr.; size of pipe, 3 in. Data from Armstrong Cork & Insulation Company.

heat-insulating values of different materials, as a number of engineers seem to think that asbestos is a heat insulator, whereas it is a very poor material for this purpose except as a binder. There are many so-called pipe coverings on the market that are worthless for anything more than the temperature used for ordinary house-heating, but they are being used in many large in-

stallations because they seem inexpensive and after they are on the pipes they look well. That there are no established standards of insulation practice is due largely to the fact that the coverings are commonly bought on a price-per-foot basis instead of on a cost-per-year basis. Competition between different makers is severe, and the temptation to unscrupulous competitors to cut prices at the expense of quality is obvious.

Durability and Efficiency Essential. On the other hand, the highest-priced insulation is by no means necessarily the most efficient. Without some knowledge of the theory of heat insulation comparison of different grades of material is impossible. The value of a heat-insulating material depends entirely on two co-essentials—efficiency and durability. Price is a minor consideration. If a covering will save its own cost in the first few years and will continue doing this as long as the plant lasts, it is

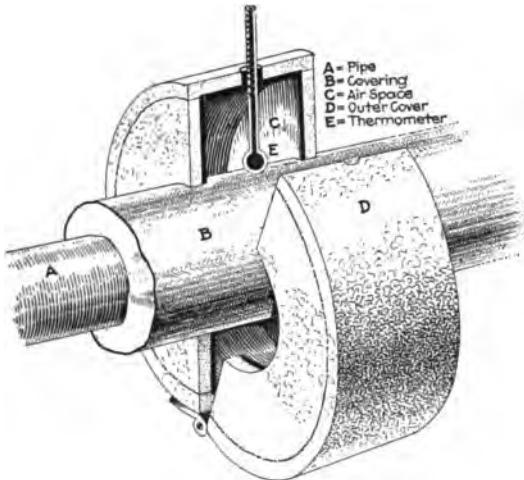


FIG. 12—SIMPLE OUTFIT FOR TESTING HEAT LOSSES FROM PIPES

Removable ends are provided to fit different-size pipes. The ends and periphery are covered with 85 per cent magnesia to prevent escape of heat. From the thermometer readings obtained the heat loss can be calculated.

a good investment. If it falls below this standard, it is dear at any price. There are some materials that will show great efficiency for a short period, but begin to deteriorate rapidly.

No pipe covering is 100 per cent efficient, but there are some that show an efficiency of from 80 to 90 per cent, the actual

figures varying according to the thickness, etc. It is quite possible to reach and maintain the larger figure by proper selection and application. In order to set up a standard of comparison, what is perhaps the best-known and most universally used insulating material will be considered—85 per cent magnesia—because it complies almost entirely with all the requirements of a perfect heat resistant both in structure and in efficiency. This material consists of an almost pure crystalline carbonate of magnesia combined with a proportion of mineral fiber (asbestos) to give it the needful structural strength. Its structure is minutely porous, the crystals of magnesia embedding between their walls an extremely large percentage of dead air. In fact, these air cells comprise by far the greater part of the material, each one hermetically sealed and so minute that millions of them are contained in a single square foot of the insulation.

A necessary consequence is that the substance itself is extremely light in weight relative to other substances. A heavy, dense material cannot possibly be a good insulation, nor on the contrary can one whose structure is so light that the air spaces visibly make up the greater part of the bulk. The general rule may be laid down that large air spaces permit circulation and therefore cannot have real insulation value.

Owing to the tremendous desiccating influence of the long-continued heat on the insulation, organic substances are necessarily barred. Otherwise there are many materials of this class that would make efficient insulating coverings.

Taking bare pipe as a standard for comparing radiation losses,¹ it can be easily calculated that from each square foot there is roughly a heat loss of 51.7 B.t.u. per degree difference of temperature per hour, or with a steam of 150 lb. (10.5 kg.) a net loss of at least 1½ lb. coal per square foot of pipe per hour, or 36 lb. per twenty-four hours. This loss is continuous as long as there is steam in the pipe and is equivalent to more than 7 tons per year per square foot of pipe. This is an extreme instance, but in so far as it is the practice to allow any kind of steam pipe or feed pipe to remain uncovered, so far do these extreme figures

¹ Steam pressures and superheats such as are used in ordinary central-station and power-plant practice are considered. These remarks are only partly applicable to heating or other low-pressure work, or to the use of furnace or other forms of heat reaction.

apply. A very few feet of uncovered or badly covered pipe will therefore waste considerable coal.

"Standard" thickness covering is intended for pressures up to 100 lb. (7 kg.) only. Above that point extra coverings are required up to the maximum temperature of about 600 deg. Fahr. (315 deg. C.), which represents the highest practical temperature in modern steam practice. Figures taken from the standard specifications of the Magnesia Association follow:

Steam Pressure (Lb.)	Thickness of Coating
Up to 100	Standard.
100 to 150	Double standard.
Over 150	3 in.
With superheat	3½ in.

Any engineer can readily compare his own insulation with these standards. If it falls short of these thicknesses, he is probably wasting a good deal of valuable heat.

Heat Insulation from an Investment Point of View. When the late Henry G. Scott made what is perhaps the only series of actual tests ever conducted by a user of insulating materials, he pointed out that the following factors should be taken into consideration in selecting heat insulation if satisfactory service is to be expected:

(1) Investment in covering; (2) cost of coal required to supply lost heat; (3) 5 per cent interest on capital invested in boilers and stokers rendered idle through having to supply lost heat; (4) guaranteed life of covering, and (5) thickness of covering. He further says: "It is apparent that the covering which shows a minimum total cost under the first three headings is the best covering to adopt, for the loss of heat at the end of ten years may readily cost more than three times as much as the first cost of the covering." That his conclusions were justified is indicated by the fact that the original (85 per cent magnesia) coverings selected by him are still in use.

In considering the investment value of an insulation durability naturally assumes importance. It goes without saying that the most durable covering will pay best, provided that it is equal in initial efficiency to others under consideration. This point demands greater attention than it often receives, because once the pipes are covered it may be years before they are disturbed again. A poor covering may have lost its efficiency in a short while, but

because there is nothing to show this externally it will continue to waste heat for many years or even until the pipes are worn out.

Following is a simple formula which will assist in determining the most economical covering for any given class of service, whether temporary or permanent $(c - a/b)b = d$. In this equation c is the value of the coal saved per year, a is the cost of the covering, b is its life in years, d is the gross return on the investment in the covering.

Thus taking the cost of 100 ft. (30.4 m.) of covering as \$80, assuming its life as fifteen years, and considering that during that time 25 tons of coal at \$4 per ton are saved per year owing to the covering, the gross return on the investment will be $(100 - 80/15)15 = \$1,420$ per 100 ft. of covering.

For comparison consider the cheapest kind of pipe covering, costing \$40, with an estimated life of five years. Assume that the coal saving is 60 per cent of that obtained with the better covering mention in the preceding paragraph. Then the gross return will be $(60 - 40/5)5 = \$260$, instead of \$1,420 with the better covering.

In applying this formula to actual practice it must be borne in mind that what is meant by "lifetime" is the efficient lifetime of the covering, during which it will give its maximum service—and not merely the time it will stay on the pipes without falling off.

HOW TO AVOID EXTRAVAGANT USE OF BOILERS

Curves plotted to show the results of operation in both the turbine room and the boiler room are used by the engineers and managers of an Indiana plant as a check against extravagant operation of boilers. The curve chart is arranged so that the number of boilers in service and the load on the plant in kilowatts are plotted against time. By using the same abscissas for both curves and by choosing a proper ordinate scale the curves fall very near together if proper operation is obtained. Any variation from normal operation is at once noticeable, owing to the wide divergence which the lines show. When this occurs the manager generally demands an explanation from the chief of the boiler room. There must always be a good reason for carrying more boilers than the chart indicates are necessary.

Data from which these curves are plotted are collected separately by the man in charge of the boiler room and the man in

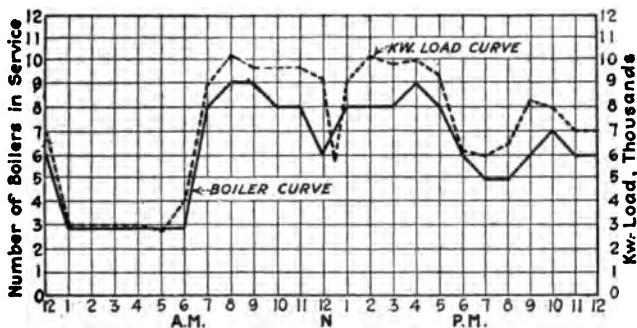


FIG. 13—BOILER CURVE SHOULD NEARLY COINCIDE WITH KW. LOAD

charge of the engine room. The relation of the two curves to each other is therefore known to the boiler-room chief only after he has turned in his data. This precludes any possibility of getting "doctored" figures into the report. To assist the boiler-room chief in holding just the right number of boilers on the line, or in readiness to go on, it was of course necessary to place in the boiler room a totalizing wattmeter to indicate the station load.

CONSERVING OIL IN BOILER ROOM

On the eccentrics which are part of chain-grate stoker drive, on stoker bearings and on economizer bearings, the Topeka (Kan.) Edison Company is using bottle oilers of the type manufactured by the Nathan Manufacturing Company and distributed through the Vacuum Oil Company. These devices are small bottles with tight-fitting plungers through which oil is obliged to leak to the bearings which it lubricates. This scheme of oiling is especially satisfactory for bearings which have been taking a large amount of low-grade oil and which can be converted to use a smaller amount of high-grade oil.

At this plant, it was formerly the practice to fill the oil cups on the stoker eccentrics twice a day. Moreover, it was always difficult to get the firemen to attend to this work. With the bottle oilers it is only necessary to renew the supply of oil once every two weeks, although the bottles are inspected by the firemen on

each shift. While a higher grade of oil is used in lubricating the bearings with the bottle oilers, only one-fourteenth as much oil is required as was used under the former system.

EMERGENCY OPERATION OF BROKEN CHAIN GRATE

An emergency arose recently in a small Western plant wherein it was necessary to operate two 400-hp. chain-grate stokers which had been taken out of service owing to holes in the grate as large as a man's hand. To permit operation under these conditions wooden barrel staves were placed over the holes as they appeared in front of the hopper. The staves prevented the coal sifting through the grates until they were nearly burned through, at which time the coal had coked enough to support itself. This scheme permitted operating the grates satisfactorily until the repair parts arrived.

FUEL SAVED BY REPAIRING LEAKS IN BOILER SETTINGS

An actual saving of fuel can easily be accomplished if a small amount of time is given to inspecting and patching leaks that occur in boiler settings. Heating and cooling of furnace walls is continuous and cracks are bound to form. Boiler settings should be inspected at least once a month with a candle flame to find the leaks, especial attention being paid to the joints around the fire and clean-out doors and around the breeching. These leaks should be marked and filled with asbestos, rope or old pipe covering. They should then be sealed over with a flexible cement made of 10 lb. (4.5 kg.) of asphalt, 10 lb. magnesia-asbestos, 10 lb. Portland cement and $\frac{1}{2}$ gal. (1.9 l.) benzine. The cement is made by heating the asphalt until fluid and then removing it from the fire and mixing it with the benzine. This mixture is then stirred in the cement and magnesia-asbestos that is already mixed and heated to 300 deg. Fahr. High-temperature surfaces to be repaired should have a covering that has a greater proportion of cement and magnesia. These leaks should also be inspected often, as they are apt to leak again. A saving of 10 to 25 per cent of fuel may easily be made by following up these leaks. These suggestions were given by the Jones Stoker Company in its official house organ.

BRAZING PIPE JOINTS TO STOP STEAM LEAKS

One of the jobs that require careful attention when steam-measuring instruments are being installed is that of connecting the joints in the small pipes leading from the steam mains to the instruments. Many companies which are now installing boiler-room instruments so as to obtain an accurate check on the efficient use of coal discover that unless their pipes are carefully installed they are liable to become leaky at the joints. The Iowa Railway & Light Company of Cedar Rapids, Ia., when it installed additional instruments in its steam plant brazed all of the joints in the small connecting pipes with the effect that no trouble has been encountered and that the instruments give correct readings.

REDUCING COSTS BY SOFTENING BOILER-FEED WATER

Unfortunately, scale cannot be blown off the tubes like soot, it being necessary in a great many cases to chisel or turbine out

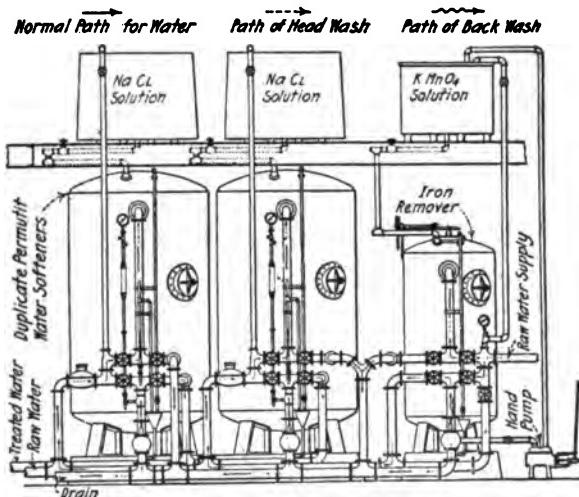


FIG. 14—ARRANGEMENT OF WATER SOFTENING AND PURIFYING TANKS USED BY ONE CENTRAL STATION

the deposit. The question is how much fuel scale really wastes and whether the waste is sufficient to warrant the investment in a water-softening plant to prevent the formation of scale.

Previous Published Data on Savings. Published experimental data on this subject are not in great abundance. Between 1898 and 1908 the engineering experiment station of the University of Illinois ran a series of tests on a locomotive and on individual boiler tubes in order to throw some light on the subject, publishing the results in its *Bulletin* 11 (1908). The locomotive, taken from the Illinois Central Railroad, was run with about $\frac{3}{64}$ in. (1.19 mm.) scale in it for about twenty-one months. Then the engine was cleaned and run for two days clean. The loss, based on equivalent water per pound coal evaporated from and at 212 deg. Fahr., amounted to 9.6 per cent. The individual boiler-tube tests with scale up to $\frac{1}{8}$ in. (3.175 mm.) thick showed widely varying losses up to 12 per cent, depending on the mechanical structure of the scale and the thickness.

An article by H. G. D. Nutting, published in the *Electrical World* (Volume 66, No. 23, page 1257), described a water-softener installed in a central station in Wisconsin. The effect of the treatment was as follows: "The coal bill has been reduced 18 per cent of its former amount, based on the same load. The coal bill for July, the second month of use of the water softener was \$514 less than for May, when the softener was not in use—i.e., based on the same output."

Railroad Experience. Railroads are the largest users of fuel in boilers for the generation of steam, and their experience is most valuable to illustrate the various operating losses due to scale. In 1905 the American Railway Engineering and Maintenance of Way Association, which has a standing committee on water service, issued a report¹ on "Comparison of the Cost of Installing and Operating Water-Softening Plants, with the Benefits Derived from Their Use." From the experience of about forty railroads with water-treatment plants it selected several as furnishing the most authentic records, each of them having installed at least fifteen or more water-softening plants up to that time.

A summary of the data given in this report follows:

The Atchison, Topeka & Santa Fé Railway installed water softeners in 1903 on divisions in Kansas and Colorado. In December, 1902, it had 456 locomotive-boiler failures from leaking. By using softened

¹ Volume 6, 1905, pages 597-611.

water failures from this cause were reduced to only sixty-eight in December, 1903, and twenty-eight in July, 1904. The average annual reduction in such failures due to water softening was 74 per cent.

As regards saving of flues, the locomotives made 363,302 miles (about 584,500 km.) more in the year ended July, 1904, than in the year previous and the store department issued 109,937 linear feet (about 33,500 m.) of flues less than the year before, which was a saving of about 20 per cent in flues. The saving in the labor of boilermakers for repairs for the same time was \$7,000.

The Chicago & Northwestern installed seventeen water softeners in 1903 on its Iowa Division, and these took care of all the natural hard-water stations in the division. The saving in the cost of labor for boilermakers was 36 per cent. The number of failures due to leaks was 583 from August, 1902, to June, 1903. The corresponding number from August, 1903, to June, 1904, was only 120, representing a reduction in failures of 79 per cent. There was also a heavier ton-mileage in 1903 than in 1902, the increase being 7 per cent. The coal saving was 4.2 per cent, since in 1902 the tonnage was handled by 28.7 lb. (13 kg.) of coal per 100 ton-miles and in 1903 by 27.5 lb. (12.47 kg.) of coal per 100 ton-miles.

Furthermore 7 per cent more tonnage was handled by fewer engines, the saving being five engines out of 159, or 3.1 per cent.

Besides the above, there are a number of benefits difficult to evaluate but extremely important as having a bearing on power-plant practice. For instance, there was a saving in time for engines to make their trips, due to fewer failures and therefore less expense for overtime labor and fewer delays for repairs on the road.

The results of eight years' use of softened water on the Southern Pacific Railroad system show a saving of 50 per cent in the expense of boiler repairs.

The average monthly locomotive mileage on the Union Pacific system has increased 27 per cent since the installation of the water-softening plants. Freight-train statistics also show "an increase in ton-miles per pound of coal of 7½ per cent and a decrease in cost of repairs per locomotive mile of 34 per cent." The saving in repairs can be seen from the increased life of flues. "The average life of a set of flues in passenger locomotives with hard water was six months; since softening the water the average life is two and one-half years."

The committee's report in conclusion attempts to describe the general water conditions under which water softeners would produce savings by stating that "it would be a benefit to soften water used in locomotive boilers that contains 15 or more grains per gallon of hardening matter, or even less than 15 grains, if the hardening matter consists largely of sulphate of lime."

There are several cases which have been experienced, however, which illustrate the possibility of severe operating losses with a water having a hardness far below the committee's limit of 15 grains. Not so long ago the chief operating engineer of one of our largest chemical manufacturing companies described the conditions existing in one of its mills using the Delaware River water, having a hardness of between 3 and 4 grains per gallon in its eight 500-hp. horizontal water-tube boilers. The engineer of

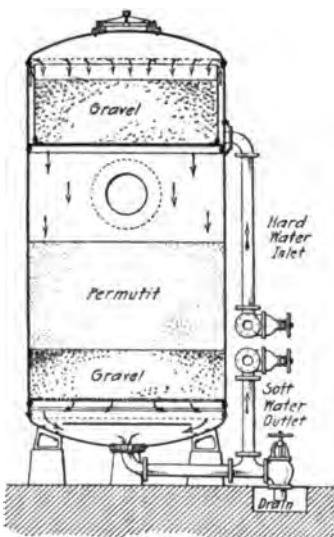


FIG. 15—EXCHANGE-SILICATE TYPE
OF WATER SOFTENER

the plant showed tube charts which gave the average life of the tubes as six to eight weeks. The boilers were in constant danger of shut-down owing to tubes suddenly failing, and in several instances there was serious loss of life. The condition was due entirely to scale, which seemed to collect in sufficient quantity in tubes to prevent circulation and so cause overheating, blistering and bagging of the tubes. This same condition is probably familiar to other users of boiler-feed waters just as soft as the Delaware River wherever the boilers are operated at high overloads continuously. A boiler operating at 200 per cent rating with a 4-grain water has just as much scale deposited in it in the same

period of time as a similar boiler operating at 100 per cent rating on an 8-grain water.

Benefits Realized by Other Central Stations. That the installation of a water softener is warranted even with very soft natural waters is borne out by two other instances: A central station in Brooklyn, N. Y., installed a water-softening plant to obtain water of zero hardness three years ago on the city supply of only 2 to 3 grains per gallon of hardness. The boilers (about forty of various types) develop a total of about 25,000 hp. and are run at high overloads during the peak periods. The use of the zero water has kept the boilers in such condition that these extreme peak ratings can be maintained with reliability and security at all times.

By installing the water softener this central power plant undoubtedly saved an investment for additional spare boilers which would be necessary to take up the load quickly in case of failure of some of the units in operation and actually saved about 50 per cent of the original investment in the cost of boiler repairs and the large amounts of soda ash formerly used directly in the boilers.

In a large textile plant at Bridgeport, Pa., using the Schuylkill River for its water supply (hardness, about 6 to 8 grains per gallon) the results of the first four months' run on "zero water," as compared with the same months of the previous year, showed a monthly saving in coal of 100 tons to 200 tons, compared with a consumption on hard water of 600 tons to 800 tons. The boiler plant consists of ten 150-hp. horizontal return-tubular boilers, the total horsepower developed being 1700. The same months in both years were chosen because the load was approximately the same during both periods.

It is interesting to note that the saving increased steadily during the four months in question because the scale was not completely removed when the water softener was started in operation. During the first month the saving was 102 tons, second month 166 tons, third month 208 tons, fourth month 216 tons. The soft water removed the old scale gradually, and the decreasing amount of scale present caused a corresponding decrease in coal used.

The old standards and ideals adopted for the quality of feed water are changing. The practice of maltreating boilers by us-

ing any water in them, then "doping" the boilers with some compound or soda ash and periodically cleaning the boilers with chisel and hammer, is a thing of the past. With boilers costing to-day \$35 to \$40 per horsepower to install they are worthy of the fine care and attention constantly given to engines. With the present practice of running boilers, especially in central stations, at 200 per cent to 300 per cent rating, and with the necessity for absolute reliability and certainty, the need for the best water with the least possible scaling contents is rapidly becoming realized.

The station operating committee of the N. E. L. A., in describing the results obtained from a water softener in a large central steam company's plant in Manhattan operating on New York City supply of 2 to 3 grains per gallon, has this to say:

The results obtained develop a fact that is of great interest—that scale will form where boilers are operated at such high rating—200 per cent—if the water contains a hardness such as is usually obtained in the average water-softening plant. That is, boilers will not be free from scale if fed with a water of 4 grains hardness; therefore a greater refinement must be obtained to meet this condition. The demand for 200 per cent of rating is growing as more and more plants are being built to operate at that rating, and greater care will have to be taken to put into such boilers water containing the least possible hardness.

FEATURES OF VARIOUS SYSTEMS OF WATER SOFTENING

Lime-Soda Type.—In general there are two broad types of water softeners to consider. One is the lime-soda type, the other is the exchange-silicate type. The former consists of adding to the water lime and soda ash in fixed amounts depending on the chemical analysis of the raw water, allowing the dosed water, thoroughly mixed with the chemicals, to settle in large tanks, and then clarifying the settled water. This may be done with the water in a cold condition or by using a heater in advance so that the chemical reactions take place with hot water. The heater softeners permit of a smaller settling tank than the cold treatment, and the softened water if properly treated may have about 3 grains per gallon of hardness instead of the cold softened water of about 5 grains. But unless there is sufficient exhaust steam available to produce a temperature of over 200 deg. Fahr., there is no economy in the heater softener over the cold type because of the rapid radiation of heat from the large exposed area of the surface of the hot settling tank and separate hot filter. Furthermore, the washing of the filter and

blowing off of sludge from the hot settling tank causes considerable loss of heat in the hot water wasted down the sewer.

The cold type of lime-soda softener may either be intermittent or continuous. The former consists of two or more settling tanks and filters with one tank being filled, dosed with the correct charge of chemicals, and then agitated in order to mix thoroughly while the other tank or tanks are settling and being used. The advantage of this type is that with waters of variable chemical composition the charge of chemicals may be suited to each tankful correctly. But the intermittent type naturally takes up a relatively large space and the foundations are expensive.

The continuous type feeds the chemical continuously into the water, which enters the settling tank at a constant rate, settling and then filtering, the water passing from chemical feed to filter without stopping. This type is as responsive as the intermittent with the average water supply where the chemical composition changes gradually, so that by analyzing the raw and treated water once a day the correct charges may be prepared for the day.

With all types of lime-soda water softeners the important things to watch are the size of the settling tank, the size and type of the filter and the allowable causticity in the treated water. In competition the size of the main parts naturally determines the cost, and unless these sizes are specified, competitive bids cannot be compared. It is just as necessary to check up a manufacturer's specification of a water softener as, for example those of a pump. With lime-soda softeners it is absolutely necessary to have a sufficient reaction and settling time to permit the chemical reaction to take place. If the settling period¹ is cut down, these chemical reactions take place after the water leaves the water softener, and clog up heaters, piping and boilers with the resulting precipitates.

Secondly, the filter should be of quartz and not of excelsior or some other medium. Sand grains catch the precipitate best and can be easily washed by reversing the flow. The filters should be designed large enough to permit a low rate of filtration,² otherwise the precipitates may slip through.

As regards the allowable hydroxide causticity in the softened water, a limit should be set for this of about 2 grains per gallon, expressed as CaCO_3 . If no limit is set, it means that the water may be overdosed to get the guaranteed hardness. This overdosing is expensive with soda

¹ The city of Columbus allows eighteen hours' settling in the municipal water-softener.

² In the city of Columbus a rate of 2 gal. per square foot per minute is allowed.

ash at 3 to 4 cents per pound, and a high causticity leads to other difficulties in boiler operation.

Exchange-Silicate Process.—The exchange-silicate process of water softening is a radical departure from the lime-soda type. The water is passed through a bed of granular insoluble sodium-aluminate-silicate, and all of the calcium and magnesium are exchanged for sodium. The exchange silicate takes the calcium and magnesium and in exchange gives its sodium to the water. The reactions are direct exchanges just as take place with soda ash in the lime-soda water softener. But the exchange silicate, being insoluble, is present in such high excess that all of the hardness is removed and a water of zero hardness results.

As explained previously, the addition of lime and soda ash reduces the hardness to 3 to 5 grains, and a causticity in the treated water results from the excess of soluble chemicals which was added to drive the reactions to those limits. Perhaps if the excess used and the resulting causticity were allowed to go high enough the hardness of the treated water might go lower. But with the exchange-silicate method the high excess is used and yet no causticity results because the silicate is insol-

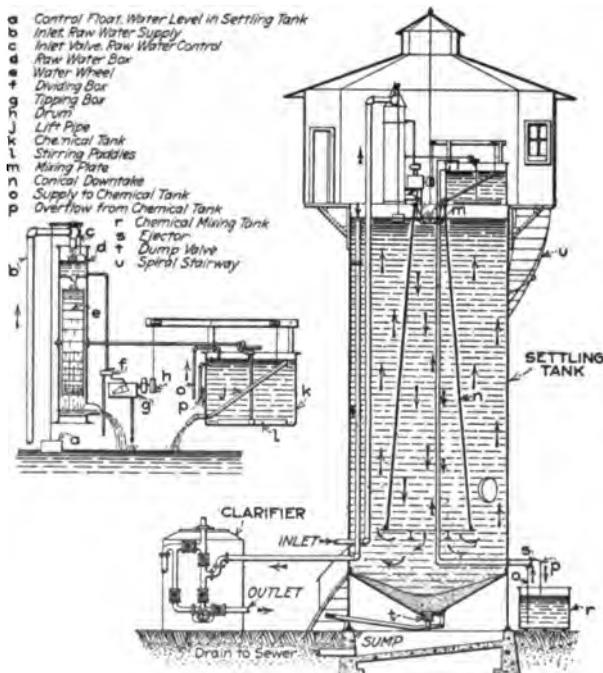


FIG. 16—ONE TYPE OF LIME-SODA WATER SOFTENER

uble. That explains why "zero" hardness water is possible by this method. The softening filters containing the exchange silicate are equipped with water meters, and when the designed capacity of a filter has been reached it is shut off and a solution of common salt or brine is introduced for about eight hours. This is called the "regeneration" period, and the salt solution restores the sodium to the exchange silicates, driving out the calcium and magnesium absorbed by the filter bed during the previous day's run. This salt is washed out and run to the drain in the morning, and the softening filter is then ready for another day's run. For continuous twenty-four hours' service two units are used in alternate service.

There are some waters, however, which can most economically be softened by a combination of the lime pre-treatment followed by the exchange-silicate filtration. This combination treatment has been strongly developed in England. In the United States also there are quite a few combination lime-exchange-silicate plants, especially in the Middle West. The advantage of the combination process over the single methods is found in large water-softening plants with waters containing a high temporary hardness of calcium and magnesium bicarbonates. The lime actually removes the temporary hardness down to several grains per gallon and so reduces the total dissolved solids in the water.

With waters of high permanent hardness, however, there is no advantage in the combination process because soda ash works by exchange on the permanent hardness just as the exchange silicates do. Furthermore about 3 lb. to 4 lb. (1.36 kg. to 1.82 kg.) of salt is needed for regeneration as against 1 lb. (0.45 kg.) of soda ash. With salt at $\frac{1}{4}$ cent a pound and soda ash at 3 cents per pound the comparative cost of removing permanent hardness by the two processes would be $1\frac{1}{8}$ cents for the exchange silicate and 3 cents for the soda ash.

Investment and Operating Costs. The comparative investments in different water-softening systems depend entirely on the composition of the water. Lime-soda plants remain fairly constant in cost with varying compositions, whereas exchange-silicate plants increase in size and cost with increase of hardness in the raw water. Cost of treatment depends also on the water composition and the proportion of temporary and permanent hardness. The cost of lime treatment alone is about one-third to one-half the cost of the corresponding salt for regeneration, but, as pointed out in the foregoing, the cost of the soda-ash treatment is about three times the cost of salt for regeneration. In conclusion, a typical case will be analyzed to determine the

actual savings that would result from installing a water softener without reference to the type used. Take a water of the following composition (same as water in the Bridgeport installation mentioned above) :

	Grains per Gal.
Total hardness,	as CaCO ₃ = 130 p.p.m. = 7.7
Calcium hardness,	as CaCO ₃ = 80 p.p.m. = 4.7
Magnesium hardness,	as CaCO ₃ = 50 p.p.m. = 3.0
Alkalinity,	as CaCO ₃ = 80 p.p.m. = 4.7
Temporary hardness,	as CaCO ₃ = 80 p.p.m. = 4.7
Permanent hardness,	as CaCO ₃ = 50 p.p.m. = 3.0

Assuming a boiler plant of 3000 hp., consisting of ten boilers with no returns using 12,000 gal. (45,400 l.) per hour raw feed water, the first cost including foundations and connections would be about \$20,000. The cost of operation for chemicals would be about 3 cents per 1000 gal. (3785 l.). With a coal consumption of 1 lb. (0.45 kg.) per 8 lb. (3.62 kg.) of water evaporated, the average daily consumption of coal would be about 150 tons. Assuming a price for coal at \$4 per ton and a saving of 5 per cent for fuel, then the fixed and operating charges of water softener would be

288,000 gal. per day × 3 cents = \$8.64.....	\$3,150
Labor of operation	= 500
Interest and depreciation, at 10 per cent.....	= 2,000

Total \$5,650

SAVINGS:

Coal.—150 tons × 5 per cent = 7½ tons per day = 2740 tons per year, at \$4 = \$10,960

Cleaning boilers.—Assuming that the boilers were formerly cleaned six times per year and are now only inspected, six cleanings saved, at \$30 per boiler, 6 × \$30 × \$10 = 1,800

Tube saving and repairs = 1,000

Total \$13,760

Deduct 5,650

Net saving \$8,110

Therefore the return on investment = \$8,110/20,000 = 41 per cent, or the plant would be paid for in two and one-half years out of the savings.

If the plant were operating condensing at considerably above normal rating, as is usually the case in central stations, the net

saving would be much greater and the softener would pay for itself more quickly, probably inside a year. This statement is based on the assumption that the percentage saving in fuel is the same in both cases and does not take into consideration the value of having more reliable service, the avoidance of damage from bursting tubes, the expense of shut-downs, or the investment otherwise required in reserve boilers. Each case should be studied individually and the water analyzed by a chemist.

AVOIDING THE PREVENTABLE SOOT LOSS

During recent years the boiler room has gradually emerged from a position of secondary importance to a primary element in the cost of power generation. Boilers have been growing in size, combustion rates have increased, and greater loads per unit of steam-making surface are being carried. With the operating conditions becoming more severe and fuel cost high above the normal level of years past, closer scrutiny is being given to all factors affecting economy.

Loss from Soot Formation. Of all the preventable losses, that caused by the formation of soot on the fire surfaces of the boiler is perhaps the most troublesome. Cracks in the setting may be detected and the leakage of air into the setting may be stopped. Proper insulation will reduce radiation, and scale on the water surfaces may be eliminated to a large extent by the use of pure or softened water. The formation of soot and ash, however, is universal and continuous as long as there is an active fire under the boiler. Depending upon the degree of combustion and arrangement of the setting, the quantity of soot varies and its character differs with the fuel, but there is no stopping of its formation. Even if conditions were ideal and combustion complete, a heat-insulating coating composed largely of ash would form on the tube surface.

As a rule the soot found in boilers is not pure soot or carbon. It contains a varying proportion of ash, so that the color may be light gray, red, brown or black where conditions are particularly unfavorable to good combustion. In coming from the furnace the soot particles are more or less plastic and readily adhere to the metal surface of the tubes. Unless the deposit is quickly removed the carbon on the tubes near the fire will burn out in part,

fusing the various ingredients into a hard coating which increases rapidly as the gas temperature rises because of the insulation of the tubes. In water-tube boilers it is not uncommon to find on the heating surface near the fire hard clinker-like formation, in some cases bridging the tubes. Even with efficient and frequent cleaning it is practically impossible to keep the lower tubes near the fire entirely free of this slag-like formation. Further back the soot does not contain so large a percentage of ash. It is usually darker in color and the formation is not cemented together. Loose deposits rest on all retaining surfaces, such as the upper portions of the tubes.

With all kinds of fuel, then, there is formation of soot. Anthracite contains a low percentage of volatile matter, but may run high in ash, so that the deposit is largely the latter constituent and is usually of a light powdery character. With bituminous coal, high in both volatile and ash, there is a large percentage of carbon in the soot, particularly if the furnace conditions are not favorable to good combustion. In waste-heat boilers deposits of fine powdered dust carried along with the gas are to be found, and even with oil fuel there is some formation of soot. Owing to excellent combustion the quantity is small, but as the deposit is pure soot of high insulating value, its removal is important from an efficiency standpoint. The soot evil also extends to the economizer, the deposits resembling the boiler soots. Because of the lower temperatures the formation is more profuse and its interference with heat transmission relatively greater as the difference in temperature between gas and water is less.

It has been commonly stated that next to loose wool loose lamp-black or soot is the best insulator known. In this respect it is ahead of hair felt and is more than five times as effective as fine asbestos. All this may be true, but boiler soot is not all lamp-black. The varying percentages of ash and the density and structure of the deposit will naturally affect the insulating properties. Besides, the coating is not evenly distributed, so that part of the surface at least will be comparatively clean. If the maximum heat transfer through the boiler tubes is to be maintained, however, all of the heating surface must be kept clean, and this is particularly true where boilers are forced over normal rating, as is the practice in modern plants. If the soot is allowed to remain, another bad feature is the formation of carbonic and

sulphuric acids, which act on the metal of the boiler, causing leaky tubes and general deterioration that will shorten the useful life of the boiler. It is quite evident, then, that soot must be removed if the best results are to be obtained, and the question at issue is the easiest and most efficient method of doing this.

Methods of Removing Soot. For this purpose there are the hand lance and the mechanical blower. The former, consisting of a rubber hose and nozzle, was the first device to be used. It is, of course, very simple, and the initial cost is small. Two men are required to operate it—one at the boiler to handle the nozzle and the other at the steam valve. The work is naturally hot, dirty and disagreeable, and on a medium-sized boiler it takes from twenty to thirty minutes. Usually there are not more than

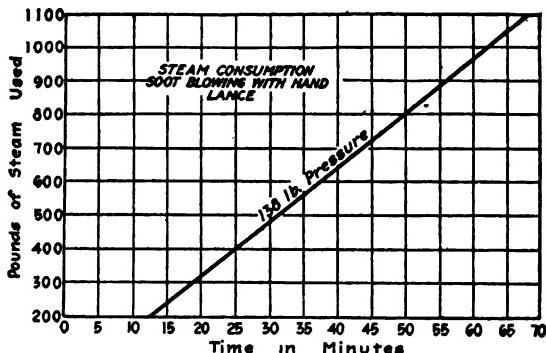


FIG. 17—STEAM CONSUMPTION WITH HAND LANCE

one or at most two blowings per day of twenty-four hours. The lance is inserted through dusting doors in the setting, and there is no opportunity for the operator to see the result of his work. Unless he is conscientious beyond the average the surface may be poorly cleaned and some sections be neglected entirely. Usually the lance does not reach all of the heating surface, the area covered being determined by the kind of dusting doors, the width of alley space at the side of the boiler and the range of the lance due to the angle of the dusting door. Another objection commonly advanced against hand blowing is the fact that when soot is blown across the tops of the tubes it strikes the battery wall and tends to pile upon the far tubes, contrary to the argument that the draft will carry it off. Moreover, there is the additional

objection of large quantities of cold air being drawn into the setting during the period the steam lance is in operation. This means less efficient combustion.

Labor is another item entering into the comparison. The mechanical blower requires but one man, and the time of blowing is, say, one-fourth as long, so that the ratio is eight to one. With very large boilers it may be considerably higher. Local conditions, size of plant, etc., determine whether the saving in time will be sufficient to dispense with the services of employees retained for this work.

Objections offered to the mechanical blower are initial cost, running from 5 to 10 per cent of the cost of the boiler, the burning out of the elements exposed to the hottest gases direct from

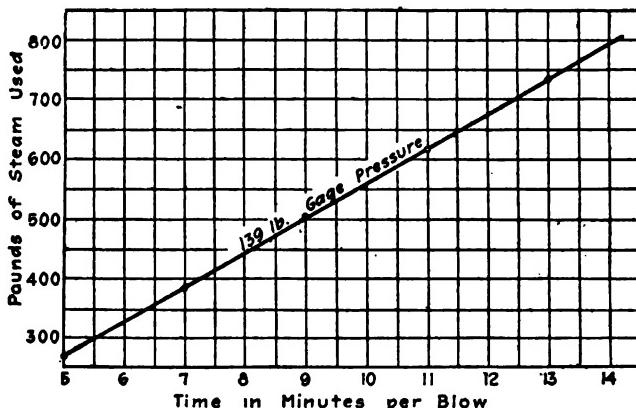


FIG. 18—TOTAL STEAM REQUIRED FOR PERIOD BLOWER IS IN OPERATION

the furnace, and warping. The objection last named, warping, has always been a serious problem. It is a well-known fact that metal begins to warp long before it reaches a temperature that will cause corrosion or burning of the metal. For that reason it is necessary to construct the element so that it will have strength to resist the warping; for as soon as this action begins the element will be thrown out of line, it will bind in the bearings and the operator will be unable to turn it.

The initial cost is comparatively small when compared to a 5 per cent saving in the fuel bill, the reduction in labor and the convenience of operation. Destruction of the elements near the fire has been obviated to some extent by the use of special metal

having high heat-resisting qualities and by so placing the elements that they are protected from the direct heat of the furnace when in the non-operating position. Corrosion, due to back suction of the boiler gases into the blowing elements, has been reduced by the use of special air valves, and special precautions have been taken to drain the piping system of the blower to prevent condensation being forced out onto the heating surface to interfere with soot removal and to corrode the metal. These various improvements, better placing of the elements and nozzles of improved design have so perfected the mechanical blower that, according to reports from numerous users, the services rendered are excellent and the maintenance charges are comparatively small.

While users of the mechanical soot blowers realize that they are getting better heat transfer, that the flue gases are lower in temperature and that the boiler efficiency has been improved, there is a lamentable lack of specific data showing the saving actually effected and the average cost of maintenance. The blowers have been installed. They are giving satisfaction. The boilers will carry more load, and it is known that the flue temperatures are considerably lower than previous to the installation. During the first two or three years of use repair parts are required occasionally. Depending upon the service, the average life of the blower is at least five or six years. The labor of blowing has been reduced, and as the work is less arduous, it is performed more frequently and with better results.

Such was the gist of replies from a large number of power-plant owners and engineers to whom inquiries had been sent by the *Electrical World* concerning the saving in fuel and labor effected by the installation of mechanical blowers, the cost of maintenance and the degree of satisfaction the blowers gave in service. The substance of some of the replies, more specific than others, is presented in the following:

The Iowa Falls Electric Company has equipped three Edge Moor water-tube boilers of the four-pass type with soot blowers. Two of the boilers were rated at 410 hp. and the other at 550 hp. The boilers had previously been blown by hand, and the work required the full time of one man at a cost of \$850 per year. In the company's opinion it took a remarkably good man to stand up beside a hot boiler and blow every tube. Frequently some of

the tubes were missed, and the result was a reduction in efficiency. Besides, a man could not hold a hose carrying 175-lb. (12.3 kg. per sq. cm.) steam pressure. It had taken the company two months to get all of the old scale off the tubes caused by blowing them with wet, low-pressure steam. The principal advantage of the mechanical blower in its estimation was the fact that full boiler pressure could be used and that better results were obtained. Since the installation of the blowers the services of the man previously mentioned had been dispensed with, and the firemen were blowing the tubes twice on every shift. The saving in coal was placed at 15 per cent. The blowers had been in service one year, and the maintenance expense had been the cost of 1 pint (0.47 l.) of oil to lubricate the swing joints.

The Iowa Railway & Light Company of Cedar Rapids had installed mechanical soot blowers on twenty-nine Edge Moor water-tube boilers during a period extended from 1909 to 1918. The company knew that the blowers were a great help both in labor and economy, but could give no definite figures. It had been found that the blowers would not keep clinkers off the first row of tubes. Here was a chance for improvement.

In the plant of the Indianapolis Light & Heat Company fourteen boilers, ranging in size from 500 hp. to 800 hp., were equipped with mechanical blowers. If properly operated, the blowers saved approximately 15 per cent in fuel and labor. About 12½ per cent of this saving was attributed to higher boiler efficiency and 2½ per cent to a reduction in labor cost. The maintenance had been approximately \$5 per installation per month.

The Richmond Light & Railroad Company had blowers on ten 606-hp. B. & W. boilers, equipped with Taylor stokers. The maintenance on the blowers, which had been installed from one to two years, had been practically nothing. The company had no accurate data to show the saving in coal and labor, but was satisfied that the blowers were a good investment.

The Edison Electric Illuminating Company of Brooklyn had in use blowers on seventeen B. & W. boilers averaging 650 hp., and forty-five additional units were being installed. Installation work had begun in November, 1916, and no definite figures as to fuel saving are available, as the majority of the boilers were

still blown by hand. In the opinion of the operating engineer there was no question that the boilers were much cleaner by the use of the mechanical soot blower, and as a result a saving in fuel must result. When all of the soot blowers were installed, the labor saving would eliminate the services of five men and would amount to about \$13 per day.

Soot blowers on 4900 hp. of Stirling boilers are in use at the plant of the Indiana Railways & Light Company of Kokomo, Ind.

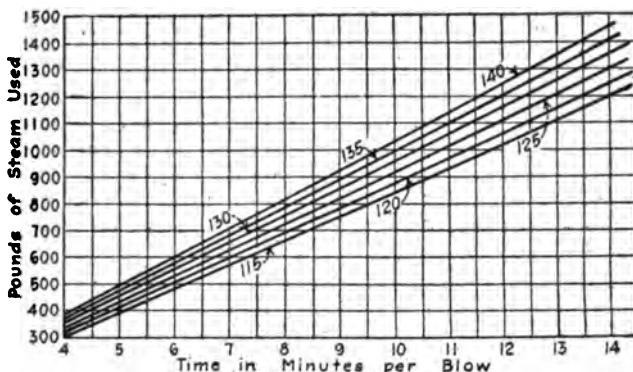


FIG. 19—STEAM CONSUMPTION OF 2-IN. BLOWER FOR VARIOUS PRESSURES

No tests have been made to determine the percentage of saving. Cleaner tubes so clearly indicated a saving that the question had not been analyzed. It had been their experience that the soot blower complete had to be removed in from five to six years.

Four 750-hp. Bigelow-Hornsby boilers in the plant of the Salem Electric Lighting Company of Salem, Mass., had been equipped with soot blowers in 1915; five blowers were installed on 280-hp. Heine boilers in the plant of the Rockland Light & Power Company of Nyack, N. Y., in 1914, and in the same year a 600-hp. B. & W. boiler of the Malden Electric Company of Malden, Mass., was equipped with a blower. In the plant first mentioned the saving in labor was \$675 per year, in the second plant \$411 per year, and in the Malden plant the labor saving was undetermined. Blower repairs in the three plants had been negligible. In the opinion of the engineering manager controlling the three properties there was no question that there had been a saving in fuel on all the boilers equipped with mechanical soot blowers, as it was possible to clean the tubes twice in twenty-four

hours so that the heating surface was maintained in much better condition. No exact data were available.

The Central Hudson Gas & Electric Company of Poughkeepsie, N. Y., had equipped six of eight Stirling boilers with mechanical blowers. These blowers were much more effective than the compressed air they had previously used, and there was a considerable reduction in labor.

Installation of soot blowers on two 400-hp. Heine water-tube boilers in the plant of the Chester Valley Electric Company of Coatesville, Pa., in the year 1911 had resulted in a saving in the operation of the plant roughly estimated at 5 per cent. The above figure was considered conservative and was divided into 1 per cent in labor and 4 per cent in fuel. The maintenance charges, which had been small, were placed at \$100 in seven years.

With blower installations on two 350-hp. Heine boilers and two Stirling boilers for several years, the Texas Power & Light Company placed the cost of upkeep at \$5 per blower per year. A saving in fuel of approximately 10 per cent was estimated over hand blowing.

The public lighting plant of the city of Detroit had installed soot blowers on two 685-hp. Stirling boilers on April 21, 1916. To clean the soot from two 400-hp. Stirling boilers by means of a steam hose from ladders required the labor of two men for about three hours. With the mechanical blowers the battery of two 685-hp. boilers was cleaned by one man in one-half hour, the ratio being twelve to one in favor of the mechanical blower. So far there has been no maintenance expense.

One of the large central-station companies of the country has equipped fifty-five boilers with mechanical soot blowers. These blowers are of competitive types, and a few of home manufacture. Fifteen of the installations have been made on Stirling boilers rated at 2365 hp. that operate all the way up to about 200 per cent of rating. On overload the temperatures are high and the conditions severe, so that it has been found necessary to assist in the further development of the blowers. To clean one of the large boilers by hand requires twelve to fourteen hours' time with two men operating. These men receive 38 cents per hour, so that the labor cost for hand blowing averages about twenty-six hours

of 38-cent time, or just under \$10 per 2500 boiler-hp. per twenty-four hours.

With soot blowers installed two men blow a boiler in about one hour. They blow each boiler three times per day, so that the total labor cost approximates \$2.30 per 2500 boiler-hp. per twenty-four hours. Thus the labor item is reduced to less than one-fourth, and the boiler has the advantage of three cleanings per day. The job is much better done, and no useless air is admitted through open doors. The effect of this factor will be appreciated when it is noticed that it takes from twelve to fourteen hours to blow one of the boilers by hand.

To clean one of the big boilers with a mechanical blower requires about 3500 lb. of steam per blow. Three operations per day would require about 10,500 lb. (4762.7 kg.) of steam per 2500 boiler-hp. every twenty-four hours.

The maintenance charges on soot blowers had not been separated from certain other somewhat similar costs, but it was estimated that soot blowers properly installed could be kept in good operating condition with a maintenance expenditure of not over \$200 per 2500 boiler-hp. per year. The average charge had been higher than this, but it was due to the fact that certain parts as originally designed and installed had given out frequently and had to be replaced. Owing to imperfect methods used for measuring flue-gas temperatures accurate data were not available to indicate the thermal advantage obtained from the use of soot blowers. It was believed safe to assume, however, that mechanical soot blowing maintained a flue-gas temperature about 30 deg. to 40 deg. lower than could be maintained with hand blowing, and unless the latter operation was completely and conscientiously done, the difference would be more nearly 80 deg. to 100 deg. less.

SAVING EFFECTED BY USE OF SOOT CLEANER

According to a soot-cleaner manufacturer, approximately 18.3 tons of coal is saved by each foot of pipe during the lifetime of the cleaner. In addition, it is said that each foot of pipe eliminates one man's labor each day which is usually required to blow the pipes with steam. Since the average water-tube boiler requires about 200 ft. (61 m.) of pipe, it is not difficult to com-

pute the total money saved or the money saved by the reduction of labor cost alone on the above basis. If it is assumed that boiler-room labor can be had as low as \$2 per day, the labor saving with the average cleaner is \$400 for the lifetime of the cleaner. As for coal saving, if it is assumed the price of coal is \$4 per ton and 200 ft. of pipe cleaner, the money saving for the lifetime of the cleaner will be about \$14,600. This amount added to the labor saving makes the total \$15,000.

Although these figures vary with labor and coal cost, they can easily be adjusted to suit any conditions. The estimates are made for boilers operated at 140 per cent rating with an average coal consumption of 4 lb. (1.8 kg.) per boiler-horsepower per hour, boilers operating twenty-four hours per day and 325 days per year. The further assumption that the life of a cleaner is seven years is verified by the experience of the United Electric Light & Power Company, New York City, which installed soot cleaners on thirty-two boilers five years ago, the cleaners having shown only slight signs of wear. Moreover, cleaners now made have a much higher safety factor than those installed five years ago because of the cast-iron-sheathed elements with which they are now equipped.

MECHANICAL INSTRUMENTS NEEDED IN A POWER HOUSE

Following is a list of instruments and measuring equipment considered essential to the most economical operation of the steam end of a modern power station, as outlined recently before Ohio station operating men by C. E. Lewis of Toledo:

For Coal.—Track scales; choice of spiral spout meter, automatic scales at each point, weighing larry, weightometer. Coal calorimeter.

For Furnaces.—Draft gages at chimney, at outlet of economizers, at uptakes of boiler and over fire; choice of U-tube type, oil-filled differential type, indicating bellows type, recording types. Pressure gages on wind box (if forced draft), U-tube type, recording type. Recording flue-gas thermometer. Recording stoker speed meter.

For Boilers.—Steam-flow meter on each boiler; choice of Pitot-tube type, Venturi type, orifice type, combination recording

steam flow, air flow, flue-gas temperature and indicating draft meter. Recording superheat thermometer. Recording blow-down meters.

For Economizers.—Four recording thermometers for gas entering, gas leaving, water entering and water leaving.

For Feed-Water Heaters.—Water meter on make-up line, on condensate line and on line leaving heater. Two recording thermometers for water entering heater. One recording thermometer for water leaving heater. Level recorder.

For Feed Pumps.—Indicating gage on suction and on discharge. Bi-record pressure gage.

For Turbines.—Indicating gages at throttle, at different stages, on bearing oil. Recording pressure gage. Superheat thermometer. Mercury vacuum gage. Barometer. Indicating thermometers. Hydrometer for air washer.

For Condensers.—Indicating or recording thermometers, or both, at exhaust steam from turbines, discharge water, injection water, air suction, condensate, condensate leaving reheater.

MEASURING DEVICES HELP PLANT ECONOMY

The one 550-hp. and two 410-hp. Edge Moor hand-fired four-pass boilers at the plant of the Iowa Falls (Iowa) Electric Company were being stoked in a more or less haphazard fashion when a new chief engineer was hired. The first thing he did was, in his own language, "to let things go blindly, as they had been going, to get a line on the firemen." This resulted in the discovery that firemen were piling a lot of coal into the furnaces, then sitting down leisurely while the steam ran up to the popping-off point and then dropped back 25 lb. or 30 lb. per square inch (1.75 kg. or 2.1 kg. per sq. cm.). At this stage they would "slug" the fire again. This was the cycle of operations day after day.

This resulted in the installation of a recording steam pressure gage. It required very little encouragement to create a friendly rivalry between shifts to see which could make the best charts. Now these same firemen have become so proficient that, with only an occasional glance at the chart, they keep the pressure range within 5 lb. per square inch (0.35 kg. per sq. cm.), which is very good for hand firing.

When this stage was reached the chief engineer, using a single Orsat machine, decided to look into the condition of the CO₂. The first samples taken from the first pass showed from 5 per cent to 6 per cent, indicating about a 35 per cent loss of fuel. The draft was then cut down over the fires and increased under the fires, and this showed a gain of 2 per cent in the CO₂. While accurate draft-measuring instruments were not available, this procedure as a cut-and-try process was continued until the samples of CO₂ show 13 per cent to 14 per cent and it was possible to carry the peak load without changing the draft. The draft is now about 0.3 in. (0.7 cm.) over the fires.

When the first pass showed this much improvement, samples were taken in the last pass. These showed 8 per cent CO₂. Experiments with the third pass gave the same results, showing that the baffling was all right. A search for air leaks was then started, which revealed a bad leak in the header. After this was stopped it was possible to get as high as 15 per cent CO₂. The boilers are now covered with a plastic cement which is very effective in keeping out air. On the whole, the plant is operating much more efficiently, owing to the installation and use of proper measuring instruments.

CHEAP SOLUTION FOR ORSAT APPARATUS

By using the waste solution from Edison batteries for the liquid potassium hydroxide usually required for a CO₂ device, the Citizens' Light & Power Company of Adrian, Mich., has found that great economy can be effected. One filling of this solution will last for a month of testing and represents an amount of potassium hydroxide that costs about \$2.75, whereas the return value of the battery solution is only about 10 cents. Furthermore, the time and trouble required for making up the solution are eliminated.

NOZZLE FOR CLEANING SURFACE CONDENSER TUBES

A simple and efficient nozzle for cleaning surface condenser tubes, which is far more rapid, yet more thorough, than the usual form of rod and brush, may be utilized where air under pressure is available. The cleaning outfit consists essentially of a piece of $\frac{1}{4}$ -in. (0.6-cm.) pipe bent to shape, a reducer, a $\frac{1}{2}$ -in.

(1.3-cm.) T, a pair of regulating valves and suitable lengths of air and water hose. Air is required under 60 lb. per sq. in. (4.2 kg. per sq. cm.) pressure or more. A check valve should be placed in the air line to obviate any chance of water getting back into the line. The head is taken off at one end of the condenser; at the other end only the hand-hole plates are removed. The nozzle is rapidly moved from tube to tube at the open end, and the dirt, consisting mostly of mud and seaweed, is expelled from the tube by the scouring action of the air and water. After the washing is complete, the ejected mud is scooped out through the hand-holes at the other end of the condenser. By this means one man can clean a 4000-kw., 10,000-sq. ft. (900-sq. m.) surface condenser, containing approximately 3400 15-ft. (4.6 m.) $2\frac{1}{4}$ -in. by $\frac{3}{4}$ -in. (7.3-cm. by 1.9-cm.) tubes, in six hours, not including the time required for removing and replacing the condenser head and plates. The operator must wear a rubber coat and a helmet.

It is stated by the station operators of the San Diego Consolidated Gas & Electric Company, who utilize this form of nozzle, that this method of cleaning is a great labor saver. When the air and water nozzle was first used hollow cylinders of mud and sewage were ejected from many of the tubes, showing the new method to be a decidedly thorough cleanser. It is understood that some central stations use sand blasts for cleaning tubes. With the particular forms of sediment encountered in San Diego, no scale being present, sand appears to be unnecessary, and the wearing action which may result from the use of sand is not experienced.

COAL PILE SPONTANEOUS COMBUSTION

Heat due to oxidation rather than pressure was given as the main cause of spontaneous combustion of bituminous coal by Prof. H. H. Stock of the University of Illinois before a meeting of the Western Society of Engineers. He said that coal should be stored so as entirely to exclude any air, or else adequate ventilation should be provided to keep the coal at a low temperature. Any intermediate conditions are dangerous and should be avoided.

Among precautions which were suggested for preventing spon-

taneous combustion were: Coals of different varieties should not be mixed while in storage, and the coal should not be piled high on account of the difficulty of moving it in case of fire. If sufficient heating occurs to raise the temperature to 150 deg. Fahr., close watch should be kept on the pile; if the temperature increases to 175 deg. Fahr., it should be moved and cooled before more coal is added. Equipment for storing coal should be arranged to make it possible to move the coal quickly in case of an emergency. To avoid the starting of fires pieces of wood and greasy waste should be carefully removed from storage piles and the coal in storage should be kept away from external sources of heat, such as steam pipes.

Common methods for testing coal piles for heat are as follows: Watching when the pile begins to steam; observing the odor, which is that of either burning bituminous matter or burning sulphur; inserting an iron rod into the pile and when drawn out testing it with the hand; inserting a thermometer into a pipe driven into the pile; observing spots of melted snow on the pile.

He said further that opinions differ in regard to the critical temperature in piles of coal. Professor Parr of the University of Illinois is of the opinion that bituminous coal can be stored without appreciable loss of heat value, provided that the temperature is not allowed to rise above 180 deg. Fahr. How close to this temperature a pile should be allowed to heat is largely a matter of judgment, for if the rise in temperature appears to be decreasing rather rapidly it may be safe to allow it to approach 180 deg. Fahr., whereas if the rise is steady and regular it is wise to load out the pile before the danger point is reached. The time also depends upon the means available for loading out the coal, for at a plant equipped with large grab buckets and means for rapidly handling the coal a higher temperature can be permitted than where a considerable time may be required to load out the coal. A person in charge of a certain kind of coal under certain climatic conditions will soon learn what the danger point is, and it is impossible to set any critical temperature that will apply to all coals under varying storage conditions. The only safe rule is to watch the pile closely and get ready to load out the coal when the temperature reaches 150 deg. Fahr. and to move the coal if the temperature reaches 175 deg. Fahr.

An interesting experiment has been carried out at the Uni-

versity of Illinois in stocking No. 6 Illinois coal mined near Georgetown, Ill. For several years it has been customary for the university to stock 4000 tons to 5000 tons of coal on the ground in piles about 12 ft. (3.7 m.) high, the coal being thrown from railroad cars onto the piles and distributed by scrapers. At times fires occurred in these piles.

During the summer and fall of 1917 a pile of about 10,000 tons of coal was placed on an old tennis court which furnished a hard foundation. This coal was piled to a depth of 10 ft. (3 m.) or 12 ft. (3.7 m.) and surrounded on three sides by a light fence 7 ft. (2.1 m.) high. The coal was transported to the tennis court by means of a motor truck, and the entire surface of the ground was covered to a depth of from 2 ft. to 5 ft. (0.6 m. to 1.5 m.). This layer of coal was then rolled with a heavy roller to pack it down tightly and exclude the air as much as possible. The fence, of course, assisted in excluding the air around the edges of the pile. Plank roads were then laid over the top of the pile so that the motor truck could dump more coal on top of the layer which had been rolled. This process was repeated continuously until the pile was completed. This method of storing coal proved rather successful. While heating developed in a couple of places where other coal had been mixed with the screenings, the method otherwise proved entirely satisfactory. The cost of storing and reclaiming coal handled in this way averaged about 40 cents per ton.

DETERMINATION OF INSULATION ECONOMY

By calculating the volume of heat loss from insulated pipes and adding the fixed expense and cost of maintaining the insulating material a decision can be reached as to the expenditure which can be economically made to insulate pipes. Curves which take these considerations into account are given in Fig. 20, the actual cost per year per square foot of surface covered being shown direct.

The horizontal lines represent the cost of upkeep, and the curves radiating from zero give the value of the heat losses at various temperature differences. The temperature difference to be used is found by subtracting the temperature of the surrounding air from the temperature of the steam in the pipes. By

adding the constant and variable costs the total expense chargeable to insulated pipes is obtained. This is shown by the remaining curves.

Referring to a handbook or similar source of information, the loss from bare pipes can be obtained and a comparison made.

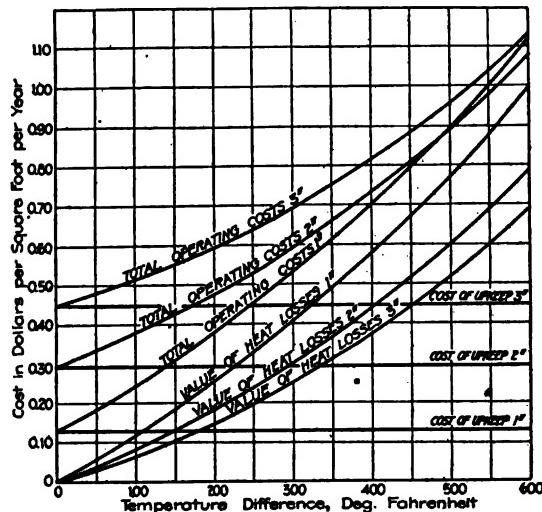


FIG. 20—TOTAL EXPENSES CHARGEABLE TO PIPE INSULATED WITH 85 PER CENT MAGNESIA

The experiments on which this chart was based were made at the Mellon Institute of Industrial Research at Pittsburg, Pa. Insulating material known as 85 per cent magnesia was used in the tests, which covered a year's time.

SPONGE-FELT INSULATION PROVES VALUE

A 2200-ft. (670-m.) length of outdoor pipe line 6 in. (15 cm.) in diameter transmitting steam having a temperature of 466 deg. Fahr. has been successfully insulated from a low temperature during the winter months by a combination of sponge and hair felt. The sponge is placed next to the pipe and covered with the hair felt. The hair felt will not withstand high temperature but makes an excellent intermediate or superficial covering. The total thickness of the heat insulation on this line is 3 in. (7.6 cm.), and tests show that the outside temperature is only slightly

above that of the air with the latter at 22 deg. Fahr. In the winter icicles formed on the line.

ASBESTOS INSULATION CONSERVES HEAT

The use of asbestos insulation between the courses of the brick settings of boilers reduces air leakage and conserves heat that is usually wasted with the ordinary air space, according to recent investigations of the United States Bureau of Mines. Firebrick should withstand temperatures up to 3000 deg. Fahr., but it is a good conductor of heat and conducts it six to ten times as fast as the asbestos felt. Red brick conducts heat about five times as fast as the felt. Insulating material with smaller air spaces reduces convection losses far better than material with the larger air spaces. This practice is especially timely with the present fuel prices, and the result shows that it is not economical to use cheaper insulations for high steam pressures. When subjected to temperatures of 1200 deg. to 1500 deg. Fahr., the disintegration of the better grade of asbestos fibers starts and the material gradually becomes more brittle, not going to pieces, however, much below 1800 deg. Fahr.

PROTECTING LAGGING ON SOOT-BLOWER PIPING

Sometimes when the side doors in a boiler setting are opened the flash of flame which comes forth is sufficient to burn the cloth covering from the magnesia which surrounds the adjacent soot-blower steam piping. The result is that the covering becomes very unsightly and the magnesia soon begins to drop from the pipes, leaving them uninsulated. Without a covering on the pipes condensation of the steam will occur, and this is undesirable in blowing soot. To eliminate this trouble the Dayton (Ohio) Power & Light Company in its new power house at Miller's Ford has covered all pipes adjacent to the doors with galvanized iron. The sheet metal is applied after the magnesia and duck are in place.

INCREASING STATION ECONOMY

Southern California being a large fuel-oil producing section, there has as yet been no real shortage of fuel there. However, oil consumption is rapidly increasing, and there are grave possi-

bilities of a real fuel-oil shortage in the near future. All possible means are therefore being devised writes J. W. Andree, Assistant Superintendent Department of Generation, Southern California Edison Company, to decrease the consumption of fuel oil. All the water powers of southern California are being utilized to their utmost, hardly a drop of water going to waste in this section which can be put into use at a reasonable cost. At the Lytle Creek plant of the Southern California Edison Company wells have been sunk in the river bed below the diversion dam, and the underflow of the river is pumped from these wells into the conduit leading to the power plant by motor-driven pumps.

On the Santa Ana River water rising below the diversion dams of the upper plants is diverted into the intake of the lower plants. The pipe lines of the Mill Creek No. 3 plant have been cleaned of all vegetable and animal growth to decrease resistance to the flow of water. Nature has lent a helping hand at this plant to increase its output. The winter rains always leave the river bed very rough and full of porous gravel, which encourages a large underflow of water. Early summer rains this year have brought down an abundance of silt and cement-like deposit, which has effectively filled many of the voids in the river bed and thus decreased the underflow, and as a result the flow of this river has been much larger than in other years of equal rainfall.

At the Mill Creek No. 2 plant water which flows under the diversion dams is diverted into the canal at a lower point. New buckets are being designed for this plant which should increase its efficiency from 10 to 15 per cent. The waterwheels in the Mill Creek No. 1 plant have been recently overhauled, and the design of the needle valve and tips has been changed to give the highest possible efficiency on the old-type equipment of this plant.

Increasing Waterwheel Efficiency. The design of the needle valves and tips of the Azusa plant is being changed to increase the efficiency of the waterwheels. The nozzle tip on one of the waterwheels at the Sierra plant has been made larger to increase the output of the plant during periods of high water. At this plant it is also contemplated to replace the old two-phase, 500-volt generators with 11,000-volt generators of modern design from the Pedley plant, operation of which has been discontinued. By doing this the electrical efficiency of the plant will be in-

creased and transformer losses will be eliminated because the generators will feed directly into the 11,000-volt distribution system.

All important transmission systems of southern California are interconnected, the larger and more efficient plants being operated at full load and the smaller and less efficient plants used only to carry peak loads. Frequency-changer sets have been placed in operation between the systems operating at different frequencies. A 5000-kw. frequency-changer set is in operation at Colton, connecting with the Southern Sierras Power Company, and similar units are in operation at San Juan Capistrano and Magunden, connecting with the San Diego Gas & Electric Company and the San Joaquin Light & Power Company respectively.

The Kern River No. 1 plant is being operated at 60 cycles on the San Joaquin Light & Power Company's system, and it in turn is feeding the Mount Whitney Power & Electric Company at the same frequency. At such times as there may be an excess of hydroelectric power on these systems the excess can be diverted to the Southern California Edison Company's system through the frequency changer at Magunden, or the generators at the Kern River No. 1 plant may be changed to the 50-cycle system. This change can be accomplished with an interruption of only fifteen minutes (on the generator being changed) if all generators are running loaded and with no interruption at all if three or fewer are in operation.

To decrease the consumption of fuel oil at the Redondo plant one-third of the total number of boilers have been equipped with furnaces for burning natural gas. Those furnaces are of the multiple-burner type, there being 180 gas jets distributed over the entire floor of the furnace. The gas enters the furnace from the front through five 2½-in. (63-mm.) extra-heavy pipe laterals extending the full depth of the furnace under the furnace floor. At intervals of about 9 in. (25 mm.) these laterals are tapped on each side for 0.5-in. (13-mm.) pipe nipples, which are capped with standard pipe caps and have a $\frac{3}{16}$ -in. (5-mm.) hole drilled in the top near the outer end. Over this opening is placed a fire-clay burner tube 15 in. (38 cm.) long and 3 in. (8 cm.) inside diameter. These tubes have a slot cut in one side which straddles the 0.5-in. nipple with the orifice in the center of the tube and 12 in. (30 cm.) from the top. The top of the tube is flush with

the floor of the furnace, and baffle bricks are laid over the tube opening to diffuse the gas flame. The furnace floor is supported on 2-in. (5-cm.) standard pipe. This furnace burns the gas very efficiently, and the flame is so evenly distributed that there is practically no danger of burning or blistering of the boiler tubes. To avoid damage to the clay-burner tubes due to expansion of the furnace floor, the floor is loosely laid with mortar containing asbestos.

These furnaces are also equipped with front-shot oil burners for use in emergency when there is a failure of the gas supply. While the efficiency of oil burners in these furnaces is not very good, still it is more economical to use them for short periods of gas interruption rather than to warm up cold boilers which are equipped with oil-burning furnaces. The oil burners can be put into operation on instant notice so there is no interruption of the supply of steam.

CAUSES OF IMPAIRED TURBINE ECONOMY

In addition to its many other advantages the steam turbine has the characteristic of maintaining its original efficiency for a considerable length of time, Josef Y. Dahlstrand, Chief Engineer, Kerr Turbine Company, states, if operated intelligently and properly maintained. In the majority of cases it can also be restored to its original efficiency with a small expenditure compared to that necessary for the same purpose on an engine.

The causes of impaired steam economy with a turbine or turbo-unit in many cases lie entirely outside of the turbine itself. In certain instances, however, the causes are found to develop right in the turbine. When steam economy is impaired it does not necessarily follow that the thermo-dynamic efficiency of the turbine affected is decreased. In some cases the thermo-dynamic efficiency might actually be increased. In the following article the steam economy of the turbine only will be considered, rather than the thermo-dynamic efficiency.

To Save Coal Operate Turbines at Rated Vacuum. Probably the most common cause of decrease in steam economy, particularly with a small turbine, is the falling off of vacuum in the exhaust chamber. Furthermore, it generally results in the most serious loss.

The effect of vacuum on the thermo-dynamic performance of the steam turbine is well recognized. Various papers and books have been published with charts giving the percentage of steam saved for each inch of vacuum. As a matter of fact, that percentage varies greatly with varying steam pressure and varies somewhat with different types of turbines, with capacities, with operating speeds, with quality of steam and, last but not least, with the percentage of the designed load developed.

The charts are of two different and distinct types. One shows the difference in steam consumption obtained with turbines designed for different vacuums. The other type illustrates the difference in steam performance obtained with a turbine designed for a certain vacuum but operated at a different vacuum. Both types are subject to variations, due to all the causes mentioned. Naturally the latter is the one which should be considered in this article.

Certain curves are shown in Fig. 21 made by Mr. Dahlstrand from actual test data on a number of 1000-kw. Kerr turbines designed for 150-lb. steam pressure (dry and saturated steam) and operating at 3600 r.p.m. with varying vacua (27 in. to 29 in., or 68.58 cm. to 73.66 cm.) and loads. These curves may be used with fairly good accuracy for turbines rated at 500 kw. to about 3000 kw. Proper correction must of course be made for steam pressure, if this is not 150 lb.

These curves are of special interest on account of the fact that they show the effect of vacuum when operating at partial loads. It will be noted that a turbine designed for 28 in. (71.12 cm.) of vacuum, and operating at 27 in. (68.58 cm.), with 25 per cent load, will have a steam rate 12 per cent in excess of that which it would have if operating at 28 in. vacuum and 25 per cent load. If, on the other hand, it was operating at 100 per cent load and 27 in. vacuum, the steam rate will be impaired only 7 per cent compared with what it would have been if operated at the rated vacuum. The explanation of this lies, as will readily be understood, in the fact that when a turbine is operated at 25 per cent load the steam is throttled before entering the first stage nozzles to a pressure very much lower than 150 lb., and the number of heat units constituting the difference in available energy between 27 in. and 28 in. vacuum becomes a much higher percentage of the total energy available for use in the turbine.

Consulting the entropy heat diagram for a verification of the correction figure, 7 per cent, between 28 in. and 27 in. vacuum, it will be found that from 150 lb. to 28 in. vacuum there is 323 B.t.u. available, excluding the effect of reheating and considering straight adiabatic expansion. From 150 lb. to 27 in. vacuum

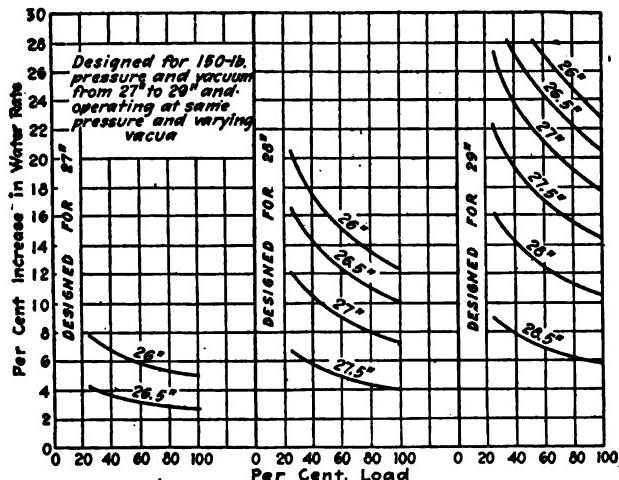


FIG. 21—EFFECT OF LOAD AND OTHER THAN RATED VACUUM ON WATER RATE

there will be found 301 B.t.u. on the same basis. According to this, there is $7\frac{1}{2}$ per cent more heat available with 28 in. vacuum than with 27 in. vacuum. The correction figure for the latter water rate on this basis should be $7\frac{1}{2}$ per cent.

There are certain factors which have a tendency to increase this correction figure. They are: First, the windage losses, which increase with the density of the steam; second, the fact that the nozzle passages in the last stages are too large for the lower vacuum, a circumstance equivalent to operating the last stages at a partial load. These circumstances, however, are generally more than outweighed by another fact.

As was mentioned before, an increase in steam consumption does not necessarily mean that the thermo-dynamic efficiency is decreased. On the contrary, it is sometimes actually increased. This happens to be true to some extent with nearly all commercial turbines of small and medium size. The thermo-dynamic efficiency is largely dependent on the "velocity ratio," or the rela-

tion between blade and steam velocities. For commercial reasons the turbine frames are actually in many cases somewhat smaller than those which would give the very best efficiency.

It might be stated here that future tendencies in steam-turbine building will probably follow somewhat different lines from recent practice. Instead of rating a turbine frame at its maximum capacity, without regard for a small loss in efficiency, indications are that the future policy will be to get the maximum efficiency even if at higher cost.

As has already been stated, low vacuum is far from uncommon, particularly in small power plants. It is not unusual to find that a turbine designed for 28 in. (71.12 cm.) of vacuum is actually operating at 25 in. (63.5 cm.) vacuum for months, owing to leaks in the exhaust line or some similar cause, with a loss of no less than 16 per cent in steam consumption. The same percentage

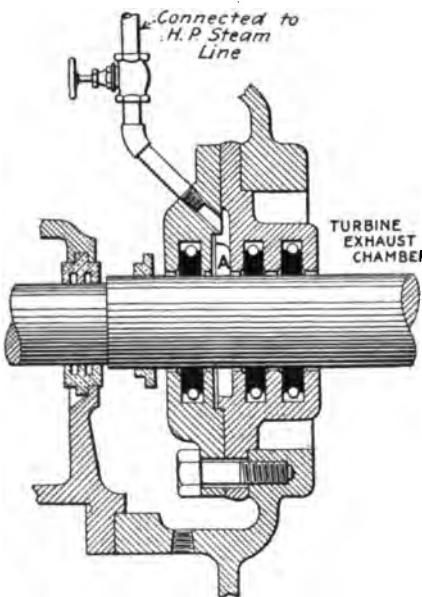


FIG. 22—GLAND FOR CONDENSING SERVICE

loss will be found in coal consumption if the low vacuum is due to air leaks, as this does not lighten the work of the auxiliaries but rather increases it.

Leaky Glands or Exhaust Pipes Reduce Vacuum. The falling off of vacuum in the exhaust chamber of the steam turbine

may be due to a number of different circumstances. The foremost of these are air leaks. These may develop in the exhaust piping between the turbine and condenser, in the condenser itself or in the turbine glands. Air may also enter through the piston-rod and valve-stem packing on condensate pumps. In addition, air may enter the condenser through the circulating water.

The exhaust-end gland of the steam turbine is generally sealed with water or steam, the simplest form of this gland for condensing service being shown in Fig. 22. This gland is commonly used for impulse turbines. It has three carbon rings with a high-pressure connection. The valve throttling the high-pressure steam is opened sufficiently so that the pressure at the right point *A* is high enough to keep the air from leaking in and at the same time not high enough to cause any excessive leakage along the shaft toward the outside of the turbine. If too great an amount of high-pressure steam is necessary to seal the gland, it is evident that the packing needs to be replaced. Assurance that there is no leakage of air into the gland may be had by adjusting the seal valve so that a very slight mist of steam escapes along the shaft.

In certain cases with low-pressure turbines, where the steam supply comes from the exhaust of a non-condensing engine, steam leaks sometimes develop in the turbine steam line. These are especially common when operating turbines at low loads, in which cases the pressure on the first-stage nozzles is generally below atmosphere. In such cases it is often advisable to install a so-called flow valve in the low-pressure steam line. This valve is so made that it will maintain ahead of itself a constant pressure, no matter what the pressure may be on the opposite side of it. It will hence prevent vacuum from entering the engine exhaust pipe, which, as stated above, generally results in infiltration of air through pipe joints or piston-rod and valve-stem packings.

The air leaks in piping and condenser are easily detected. The most common method of detecting air leaks at these points is that of bringing the flame of a candle around the joints and noting at what points the flame is drawn toward the point.

While air leaks are the most common cause for impairment in vacuum, there are others as well. A condenser which has been in service for a considerable length of time and which has been

allowed to accumulate a large amount of dirt on the surfaces will not be able to maintain the vacuum it could give in its original condition.

Excessive back pressure is just as detrimental with non-condensing machines as impaired vacuum with condensing units. This is not so common as impaired vacuum, but may be caused through carelessness on the part of operating engineers in leaving exhaust valves partly closed, etc. The effect of increased back

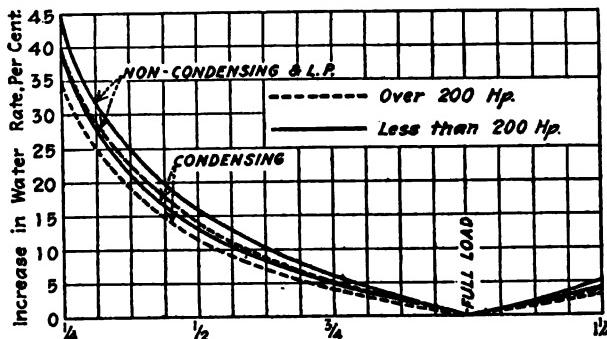


FIG. 23—EFFECT OF LOAD ON WATER RATES OF CONDENSING AND NON-CONDENSING TURBINES

pressure on the steam economy of non-condensing turbines may be realized from the following table.

Initial Steam Pressure (lb.)	Increase in Steam Consumption for Each Pound of Back Pressure (per cent)
200	1
175	1 1/4
150	1 1/2
125	2
100	2 1/2
75	3

Operation at Partial Loads Is Uneconomical. Next in its effect on the steam economy of a turbine comes the operation of turbines at partial loads. In a great many instances steam turbines are ordered for certain loads and designed for these loads. Later on it develops that they are required to operate at points very much below the full load rating of the machine. In such cases there generally results a considerable loss in steam economy. The curves shown in Fig. 23 illustrate these losses as found in tests on Kerr steam turbines.

The reason for the increased steam consumption at partial loads is obvious. The losses in the turbine do not change in proportion to the load but remain nearly constant for any load. Consequently the relation of these losses to the energy available increases for partial loads. The throttling of the steam which is found necessary for partial loads, unless hand valves are used, robs the steam turbine of some of the energy otherwise available.

The fact that a turbine is operating at partial load may be seen by observation of a steam gage which is tapped into the ring chamber ahead of the first-stage nozzles. If the pressure under normal operation at this point is considerably below boiler pressure, it is an indication that the turbine is operating under a partial load, provided of course that it was designed for only a reasonable pressure drop through the valve. The power developed with any type of turbine is very nearly proportional to the pressure at that point.

Turbines should be made to operate normally under the conditions for which they are designed. If it is necessary that they should carry overloads, overload valves—either automatic or hand operated—should be used.

Internal Leakage Should Be Avoided. Up to this point only those circumstances which arise through steam conditions and from outside sources have been considered. Certain mechanical conditions inside of the turbine may also cause a thermo-dynamic loss in the steam turbine. Foremost among them is internal leakage. This is caused by the wearing out of the packing rings or bushings or the excessive clearance of labyrinth packing between the various stages in the steam turbine.

Internal leakage is, of course, most liable to develop where the pressure differences are very great. Therefore, in certain makes of turbines the high pressure steam space is separated from the vacuum chamber with an internal gland. In cases of this kind it is always advisable to watch this gland carefully, as leaks may readily develop through it, causing a considerable loss in steam economy. Internal leakage is particularly detrimental in the high-pressure stages of a machine on account of the low specific volume of the steam in these stages, which results in a large discharge of steam through a small opening.

Leakage may also take place between the stages along the horizontal joints of the diaphragms in a multi-stage turbine. The

steam and moisture may erode the surface of these diaphragms to such an extent that a considerable amount of steam will pass through from stage to stage.

Leakage between stages as well as internal leakage may be detected by placing a gage in each stage of the turbine to give the pressure in that stage. Comparing these figures with the pressures which the turbine had when originally installed will give a good indication as to the condition in which the packings installed in the turbine are.

Steam leakage through the high-pressure gland or through the leakage piping on this gland is generally negligible. It is usually sufficiently annoying to the operating engineer, however, to lead him to try to overcome this condition. Generally losses due to this cause are greatly exaggerated by operating engineers.

Among the causes for impaired steam economy is excessive clearance between stationary and rotary elements. When this condition exists, Rateau, Curtis and other impulse turbines lose slightly in power. It would be difficult to formulate any definite rule as to the degree in which steam economy is influenced by clearance, as this varies with capacity of machine, nozzle and blade angles, etc. It is advisable, however, to bear it in mind if it becomes necessary to manipulate the thrust bearings. In general, it may be said that the rotary element should not be farther away from the stationary element than is necessary for the mechanical safety of the machine. Each case should be considered separately, however, so turbine users should consult with the manufacturers of their machines if information regarding axial clearances is desired.

With certain makes of turbines, particularly single-wheel impulse turbines, where the total pressure drop is utilized in one single expansion, considerable trouble has been experienced with erosion. This has been the case particularly with turbines in which the relative steam velocity was high—in other words, turbines having small wheel diameters or low speeds and operating condensing. Some difficulties have been experienced even with non-condensing turbines as well, particularly where the steam has been wet. If superheated steam is used, erosion is less common. Blade materials now being used in various types of steam turbines utilizing high steam velocities are being improved so as better to resist the erosive action of the steam. Erosion is abso-

lutely unknown with other types of turbines on account of the low steam velocities employed. Through erosion of the blade edges the axial clearance between the rotary and stationary elements is increased, which tends to cut down the power developed. Through the fact that these edges are made dull less perfect steam action is attained, which in turn causes a loss in power and efficiency.

Deposits on Blades Liable When Forcing Boilers. The deposits of foreign substances in the turbine blades, blocking or partly blocking the passages, might be mentioned as another cause of impaired steam economy in turbines.

This trouble usually occurs when a turbine is being fed by one or more boilers which are giving about their maximum capacity. It is more serious with some types of boilers than others. In both fire-tube and water-tube boilers there is such active circulation of water that the mud and foreign material are prevented from settling in the boiler and are mechanically lifted to the top and carried through the steam lines.

In some steel-mill districts the deposit consists principally of a muddy material which is bound together by chemicals existing in the water. At the velocity at which steam enters the blades any slight material carried in the steam will be impelled against the blades with such a velocity that it will form a very compact deposit. In a great many instances the boiler-feed water supply contains large portions of vegetable matter, as well as boiler scale-forming materials. Where this is the case the combination produces a tough, rubber-like deposit which rapidly fills the turbine blades and causes serious trouble.

Owing to the immense quantity of steam passing through large turbines a rapid increase of deposits may result even though the amount of material mechanically carried over by the boiler is very small per unit of power. It is, therefore, frequently astonishing to note the accumulated deposits when the steam is apparently quite pure and clean. Sometimes turbine blades become so clogged that sufficient power cannot be produced and the turbine has to be dismantled and cleaned.

Steam that is very wet, when made from water containing scale-forming material, such as magnesia and other salts, will invariably deposit a scale-like substance over the turbine blades. This is somewhat distinct from the deposits mentioned pre-

viously. There are other deposits which are more local in character, such as, for instance, deposits which occur in paper-mill districts, where a considerable amount of pulp is discharged in a finely divided state into rivers adjacent. The result is that this finds its way into some neighboring power plant where, owing to its fine and light nature, it is carried over by the steam and very rapidly blocks up the turbine blades. Several cases have come to the writer's attention where this occurred, the turbine having to be dismantled at regular intervals and the blades cleaned out three or four times a year.

There are various means of combating the clogging of blades from the above-mentioned causes which are effective in different degrees. One which is frequently used, particularly for non-condensing turbines, is the placing of a lubricator in the turbine steam line. The oil vapor in the steam lubricates the blade surfaces and prevents the substances from becoming attached. Even for condensing turbines this method is frequently used, although it would appear not to be entirely advisable in installations where surface condensers are used, on account of oil deposits which would be found on the tubes. Two instances are known of where this method is used with turbines rated at 10,000 kw.

Undoubtedly the most effective means of preventing this trouble is that of installing a large receiver in the steam line. The steam velocity will be decreased greatly while passing through this receiver and the foreign substances will be deposited on the walls. In addition to the receiver there should be installed near the turbine throttle a steam separator which will serve the double purpose of removing from the steam any remaining foreign substances and extracting a great deal of moisture from the steam. It might in some cases be advisable to combine these two apparatus and install a so-called receiver-separator, in which case the foreign materials will be deposited on the baffles.

GETTING THE MOST OUT OF TURBO-GENERATORS

With the advent of the modern horizontal-shaft steam-turbine generator, the ratio of the total kilowatt capacity to the cubical contents of power-plant engine rooms has increased at least two-

fold or threefold. The necessity for adequate ventilation must, therefore, be recognized in order that a safe operating temperature for the electrical apparatus may be maintained and extreme engine-room temperatures avoided for the comfort of the attendants, according to L. H. Parker and J. J. Preble of the Spray Engineering Company.

The enormous quantity of air required for ventilating large generators is perhaps better understood when the actual weights are considered. Assume, for example, a 20,000-kva. machine requiring 65,000 cu. ft. (1840 cu. m.) of air per minute. As this amount of air weighs about $2\frac{1}{2}$ tons, the generator will handle an amount of air equal in weight to its own weight in from one-half to three-quarters of an hour.

While no one questions the necessity of supplying a generator with a sufficient amount of ventilating air, there are many who do not give the temperature and quality of the air sufficient consideration. The turbine manufacturers equip their machines with fans designed for handling the proper volume of air, but upon the consulting engineer, manager or superintendent of the plant falls the duty of seeing that adequate air-conditioning apparatus is installed, so that the machines will also receive cool and clean air. One effective device that can be used for this purpose is a properly designed water-spray type of air washer and cooler.

Cleanliness and Temperature. Air in almost any locality contains considerable dust and dirt. In the vicinity of power plants it may be assumed that roughly one-hundred millionth of the volume of the air consists of dust, dirt and other foreign particles. This would mean that with a machine handling 65,000 cu. ft. (1840 cu. m.) of air per minute, as mentioned heretofore, a total of 93,600,000 cu. ft. (2,650,000 cu. m.) would be handled in twenty-four hours. On this basis the amount of dirt passing through the machine in this period would be 0.936 cu. ft. (0.026 cu. m.), or 86 cu. ft. (2.4 cu. m.) in three months.

A certain proportion of this, because of air swirls and eddies, will necessarily be deposited in the air passages. Such deposits of dirt become a serious handicap to the ventilation. The air passages become partly clogged, causing a decrease in the quantity of air handled, and the cooling effect is greatly diminished owing to the fact that air cannot come in direct contact with the heat-radiating surfaces. Air taken from the inside of a power

plant usually contains oily vapors, which make accumulations on the air passages rapid.

Unwashed air means dirty generators and excessive heating, which not only reduces the electrical efficiency but shortens the life of the insulation. Unless the machines are taken apart and cleaned periodically, grounds and even burn-outs are liable to occur. The cost of thoroughly cleaning a generator amounts to considerable, and under average conditions this has to be done about twice a year. The expense of dismantling and cleaning a 10,000-kw. unit would be about \$500 for each operation, without taking into consideration the revenue lost owing to the machine being out of commission.

Since a generator which receives clean air is comparatively free from all such troubles, it is apparent that an air washer will practically eliminate any danger of a serious accident, with a resulting loss that might exceed many times the cost of the installation.

As all modern units are designed for a certain allowable maximum temperature in the armature and field windings, the temperature of a generator with a given load will be a fixed amount above the temperature of the ingoing ventilating air, which must be well below the critical temperature of the insulation. The cooler the air delivered to a generator, therefore, the greater will be its load-carrying capacity.

The permissible load on a turbo-alternator may, therefore, be expressed as a function of the temperature of the ingoing air. This relation¹ is given in Table based on representative 25-cycle and 60-cycle machines. The load is based on a fixed maximum temperature attained by any part of the windings. Since 25 deg. C. (77 deg. Fahr.) is a standard air temperature for electrical machinery, the load at this temperature is taken at 100 per cent.

The cooling which can be obtained by the use of air washing and cooling equipment varies with the make and type of washer. For use with electrical equipment a washer should be capable of reducing the temperature of the entering air at least 85 per cent. of the initial wet-bulb depression. Table shows the cooling effect with a washer of this class, using some of the higher temperatures given above, with different humidities.

¹ Curve given in *General Electric Review*, September, 1913.

It is possible, therefore, with this class of washer to increase the safe load-carrying capacity within the above temperature ranges from a maximum of 22 per cent. to a minimum of 3 per cent. With a washer that will cool to the wet-bulb temperature

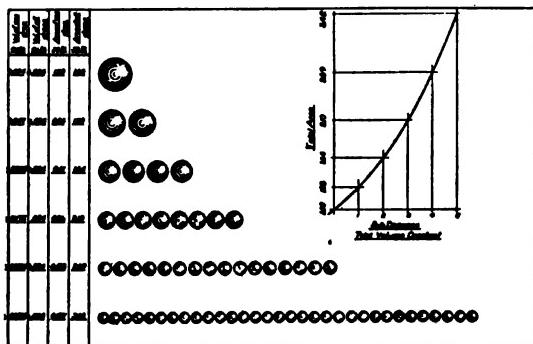


FIG. 24—HEAT-ABSORBING AND CLEANING ABILITY OF ONE DROP MORE THAN TREBLED BY SUBDIVISION

there is, of course, a further gain. Consequently, it is fair to assume that under average atmospheric conditions in the United States during the summer months the gain in load-carrying capacity would be at least 5 per cent.

When Will it Pay to Install Air Washers? There are various ways of figuring whether an investment in air washers is actually justified. One way is considered in the following: Assume a typical modern steam-turbine power station containing three 10,000-kw. turbo-generator units. A plant of this size would cost about \$3,000,000 if built to-day. During the four summer months the permissible load on the generators would be reduced from full-load rating about 5 per cent. on the average, on account of the warm atmospheric conditions. In most stations it is either necessary or desirable to operate at rated full load during this period.

In order to generate the full 30,000 kw. during the hot months it would, therefore, be necessary to do one of three things, (1) install air washers; (2) increase the size of the electrical end of the units, or (3) install a spare unit. For illustration it is sufficient to compare the first two.

Each of the 10,000-kw. machines would require a washer of 40,000-cu.-ft.-per-minute (1120 cu.-m.-per-minute) capacity, and

the total cost of the three washers would be about \$7,500. The fixed charges on this investment, including interest, taxes, insurance, maintenance and depreciation (taken at 15 per cent.), are

TABLE I—TURBO-ALTERNATOR LOAD AS A FUNCTION OF INGOING-AIR TEMPERATURE

Temperature of Ingoing Air		Load in Percentage of Load at 25 Deg. C.
Deg. C.	Deg. Fahr.	
5	41	123
10	50	118
15	59	112
20	68	106
25	77	100
30	86	92
35	95	82
40	104	70

\$1,125 per annum. Adding to this \$250, the operating cost of three 7½-hp. pump motors run one-third of the time, gives a total expense of \$1,375 per year for the air-washer installation.

On the other hand, if it be assumed that the size of the electrical-end equipment is increased 5 per cent. (which, of course, is low) so that full load may be carried at all times, the extra cost would be about \$30,000, figured at \$20 per kilowatt. The fixed charges on this, at 15 per cent., are \$4,500. Adding to this the cost of dismantling and cleansing the machines once per year at \$500 per unit, the total yearly expense would be \$6,500.

The net saving by installing air washers would therefore be \$4,625 per annum for this 30,000-kw. station, or at the rate of about 15½ cents per kilowatt per annum. In other words, even

TABLE II—COOLING EFFECT WITH SPRAY-TYPE WASHER

Relative humidity, per cent	40	50	60	70
Temperature of Entering Air, Deg. Fahr.	Temperature of Air Leaving Washer, Deg. Fahr. (85 per Cent Wet-Bulb Depression)			
68	56	59	60½	62½
77	63½	66	68½	71
86	71	74	77	79
95	78	81½	85	87½
104	86	89½	93	96

on this conservative basis, the washers would pay for themselves in a little more than one and one-half years, without taking into account the benefits accruing from washed air, such as the insurance against accident and the losses incurred when the machines are out of commission for repairs and cleaning.

When about to purchase an air washing and cooling apparatus for this service, there are several items which, from an engineering standpoint, should not be overlooked. Merely to ask for a quotation on a washer of a certain capacity is comparable to asking for a quotation on a pump capable of handling a definite quantity of water, without regard to type, efficiency, speed or materials of construction.

Characteristics Which Should Be Required in Air Washers.

In order to be efficient as regards both cleansing and cooling, and properly constructed, it is of prime importance that:

(1) The washer be provided with nozzles or other means of spraying the water, so that it will be finely atomized. The smaller the individual drops composing the spray, the greater will be the exposed surface for a given quantity of water. Therefore, both the cooling, due to evaporation, and the cleansing, due to the larger number of falling water particles, will be greatly increased.

(2) High pressures should be avoided, and the centrifugal pumps used for recirculating the spray water should be designed for high efficiency, so that the expenditure of power will not be excessive.

(3) The spray chamber should be completely filled with a dense mass of fine spray. Water curtains, or contrivances producing sheets of water, should be avoided, as, in order to pass, the air must necessarily punch holes in the sheet, which means that a considerable proportion of the air will not be properly cleaned or cooled.

(4) Means should be provided for completely eliminating all free moisture from the air before it leaves the washer. This should be accomplished without the use of heater coils.

(5) The materials used in the construction of the washer, as well as the workmanship, should assure long life. This requirement is met in one type of washer by using nozzles of bronze, screens of copper, casing and water box of heavy galvanized iron; eliminator plates, galvanized after fabrication; piping, galvanized; pump, bronze-fitted with inclosed impeller.

(6) The drop in air pressure through the washer should not be excessive. The allowable resistance measured at the inlet end of most generators is $\frac{1}{2}$ -in. (1.27-cm.) water gage, and the drop through the washer should therefore not exceed this, or the

amount of air which can be handled will be diminished. The exact air requirements are usually given in the generator contract specifications or can be obtained from the manufacturers.

By way of further explanation, it may be added that the spray chamber should be of proper depth and the velocity of the air low enough to allow sufficient time for contact between the air and water spray. Obviously, the more efficient the nozzle, the higher the permissible air velocity, and consequently the more compact the air washer. Economy of space is of great importance in power plant work. Nozzles which produce a full conical spray of finely divided particles of water at medium operating pressures are well adapted for this class of work. Spray-atomizing screens are used advantageously on one of the well-known makes of washers in order to increase the atomization of the water.

Not long ago there were very few, if any, water-spray-type air-conditioning outfits used in connection with the ventilation of electrical machinery. To-day there are several hundred power plants in this country equipped with air washing and cooling apparatus, including practically all of the large well-known stations. The resulting gain in efficiency and capacity, the saving in maintenance and the longer life of the machines to which they are attached make the installation of air washers inevitable in all progressive and up-to-date power plants.

INCREASING GENERATOR RATING BY PRECOOLING VENTILATING AIR

The question of whether to install air washers or humidifiers for conditioning and cooling the air entering generators is particularly pertinent at this time, writes Joseph T. Foster of the Public Service Electric Company of New Jersey, since by cooling this air the generator capacity may be increased from 10 to 20 per cent. Furthermore, by cleaning the air possible shut-downs for generator cleaning and, what is more serious, possible burn-outs due to heavily loaded, dirty machines, may be avoided. Obviously, then, this is the quickest and cheapest method of increasing power plant capacity.

The purpose of central station companies in including the air washer as standard equipment on turbo-generator installations is twofold:

1. For supplying clean air, free from dust which would coat the windings of the generator and form an insulating covering.

2. For precooling the air by evaporation of water when the air passes through the film of water atomized by the spray nozzles.

Before air-washing equipment was used it was found that the dust and dirt incidental to the unloading of coal and the disposal of ashes fouled the generator by coating the air passages. It was therefore necessary to shut down the generator at least once a year for a period of five or six days for cleaning purposes. In addition to the expense of cleaning, there was the inconvenience and loss of revenue due to shutting down the unit.

Some idea of the cleansing effected by a modern-type air washer can be gained from tests which showed that it was possible

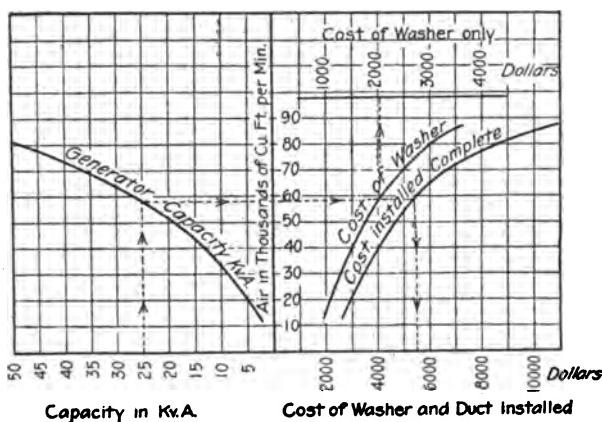


FIG. 25—RELATION BETWEEN KVA. RATING, AMOUNT OF COOLING AIR REQUIRED PER MINUTE, COST OF AIR WASHER AND COST OF WASHER INSTALLED COMPLETE

to blow several pounds of soot per minute into the intake and have the air at the generator inlet perfectly free from dust.

There is a more or less widespread belief that the humidifying of the air increases its cooling capacity on the ground that wet air, on account of its higher specific heat, has greater heat-absorbing properties. The effect of this change in specific heat is negligible as far as heat absorption is concerned, because the weight of water vapor present even in saturated air is very small as compared with the weight of the air itself. The difference in the amount of heat absorbed by saturated air as compared with dry

air under a given set of conditions is not more than 1 or 2 per cent.

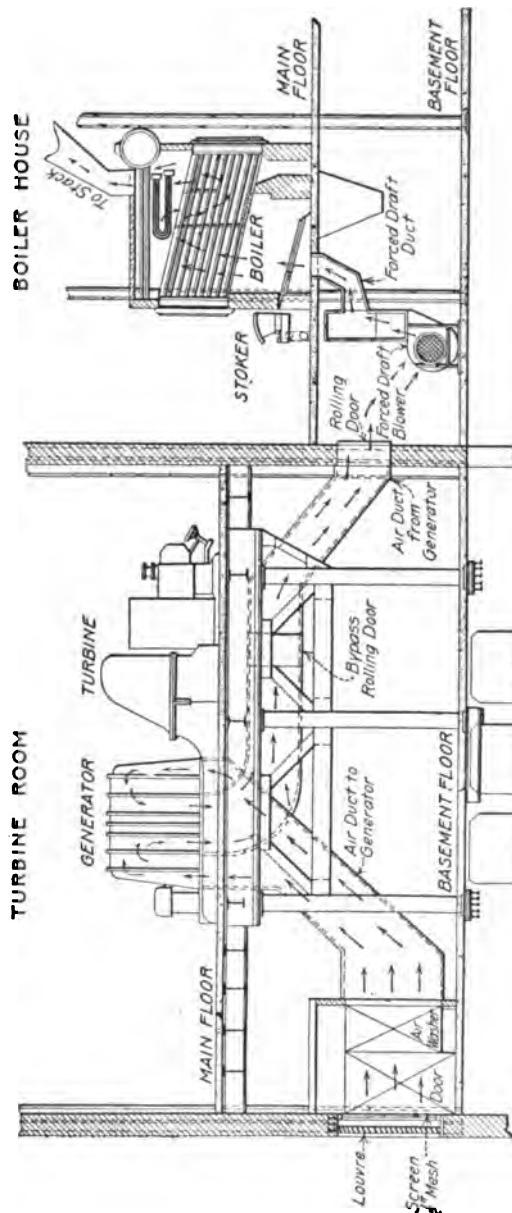


Fig. 26—TYPICAL ARRANGEMENT OF AIR-PRECOOLING APPARATUS FOR TURBOGENERATOR

The precooling action of the air washer is, however, of importance. Assume a 12,500-kva. unit which requires 30,000 cu. ft. (850 cu. m.) of cooling air per minute and in which the losses amount to approximately 300 kw. at full load. The heat absorbed per hour, assuming a final temperature of 100 deg. Fahr. (37.8 deg. C.), neglecting the moisture in the air, will be as follows:

I. Air not precooled and entering the generator at 68 deg. Fahr., $0.24 \times 0.07524 \times 1,800,000 (100 - 68) = 1,040,000$ B.t.u.'s per hour.

II. Air originally at 68 deg. Fahr., but cooled in the washer to 53 deg. Fahr., $0.24 \times 0.07788 \times 1,800,000 (100 - 53) = 1,580,000$ B.t.u.'s per hour.

In the first case, the losses absorbed amount to 1,040,000 B.t.u.'s per hour, or 305 kw.; in the second to 1,580,000 B.t.u.'s per hour, or 463 kw. It may be assumed with fair accuracy that the losses are proportional to the squares of the currents; therefore, $I_2^2/I_1^2 = 463/305$, or $I_2 = 1.23I_1$. The terminal voltage is, of course, constant, hence the kilowatt output when the air is precooled will be theoretically 23 per cent greater than with air at the higher temperature. It is more probable, however, that in practice the gain under the conditions stated would amount to 15 per cent, although gains of 20 to 25 per cent have been realized even where the natural conditions were particularly adverse.

The gain in generating capacity obtained by precooling the ventilating air is large, but is obtained by the expenditure of a comparatively small amount of money, as shown in Fig. 25.

The use of the chart is illustrated by the following:

Problem.—Given a 25,000-kva. generator, to find the amount of cooling air required, the cost of the air washer and the cost of the washer installed in place.

Solution.—From the intersection of the vertical line through 25,000 kva. and the curve, run horizontally to the vertical scale. The required air is 58,000 cu. ft. (1640 cu. m.) per minute. Running horizontally to the intersection with the first curve, read on the upper scale the cost of the air washer as \$2,050. Running horizontally to the second curve, read on the lower scale \$5,500 as the cost of the complete installation.

An illustration of an air-washer installation used in connection with a turbine plant is shown in Fig. 26. The air, which is

drawn through louvers and screens at the left, passes through the washer and then through the generator, from which it is discharged direct to the forced-draft blowers in the boiler-house basement.

This method of operation is employed during summer weather when it is desired to obtain the coolest air possible for the generator. The discharge to the forced draft blowers of this quantity of heated air improves the boiler efficiency somewhat and maintains a lower turbine-room temperature.

Under winter conditions the louver opening in the outside wall is closed by a rolling door and the air is drawn into the washer from the turbine room through the side door and discharged from the generator bypass through the sliding door provided for that purpose. Under these conditions the door into the boiler-room basement is closed.

This method of recirculating the air from the turbine room keeps the room at a comfortable temperature. It also does away with the inconvenience of having a partial vacuum in the turbine room due to the removal of large quantities of air from an inclosed space.

The washer to be purchased by the engineer should be of the size specified or recommended by the generator manufacturer, of the heaviest and most durable material, and able to cool the air to at least 85 per cent of the difference between the wet and dry bulbs. At the same time the air resistance through the washer should not exceed 0.375 in. (9.3 mm.) of water and the power consumption should be kept down to a minimum.

CHARTING INSTRUCTIONS TO GET BETTER ECONOMIES

Realizing that the over-all efficiency of its station will reach its maximum if the various generating units are combined to run at the most economical loads for the particular load condition encountered, the Moline-Rock Island Manufacturing Company, Davenport, Iowa, has worked out a scheme for showing its plant operators how to combine the generators to get the best results. Tests were run on the units to determine their efficiencies in terms of steam consumption at various loads within their ratings. While the results of these tests (Fig. 27) can be used by any one

having technical skill and judgment to determine the proper combination of machines to carry any load, the company desired to

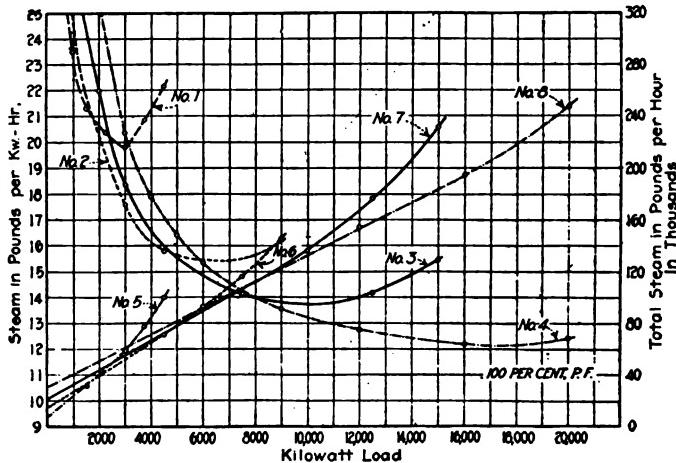


FIG. 27—STEAM CONSUMPTION OF DIFFERENT UNITS

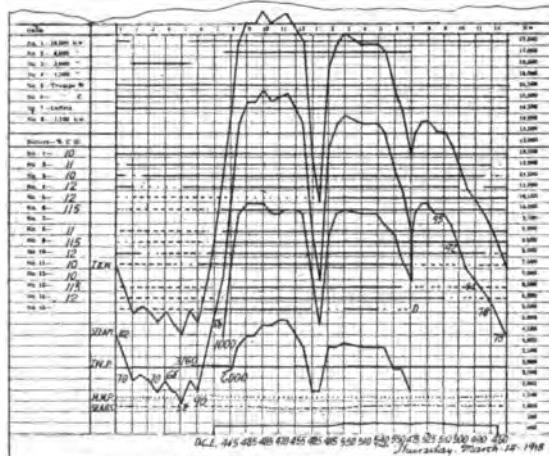


FIG. 28—PORTION OF LOG SHEET USED BY DAVENPORT (IOWA) COMPANY

Curves Nos. 1 and 5 represent the water rates and total steam consumption of a 3000-kw. turbine at 100 per cent power factor and 0 deg. superheat; Nos. 2 and 6 represent the corresponding quantities for a 6000-kw. turbine at 90 per cent power factor and 100 deg. superheat; Nos. 3 and 7, the values for a 10,000-kw. turbine at 95 per cent power factor and 100 deg. superheat, and Nos. 4 and 8, the values for a 20,000-kva. turbine at 80 per cent power factor and 125 deg. superheat.

present the information in such form that any operator, regardless of his technical judgment, may determine instantly what to do under ordinary conditions. Consequently all of the more common operating conditions that are likely to arise are listed in a table like that shown herewith, giving the combinations of units to use and the loads on which each unit shall be operated. With this table the operator needs to do no figuring and does not even have to consult the curve sheet.

As a detail in connection with the actual making of these charts and curves, it is interesting to observe that the tabulated data are blue-printed on separate sheets and then pasted on the curve sheet. This saves time in changing the tracings as well as the curve sheets when changes in the operating schedule are necessary.

CHART OF TURBINES TO OPERATE AT DIFFERENT LOADS TO RELIEVE OPERATOR FROM NECESSITY OF RELYING ON HIS OWN JUDGMENT

Kw. Load	Units in Service	Kw. Load per Respective Unit
Up to 1750	3,000	Total load
1,750-4,500	6,000	Total load
4,500-8,000	10,000 ¹	Total load
10,000	10,000	8,000- 9,000
	6,000	2,000- 1,000
12,000	10,000	9,000- 8,000
	6,000	3,000- 4,000
14,000	10,000	10,000- 9,000
	6,000	4,000- 5,000
16,000	10,000	10,500-11,000
	6,000	5,300- 4,800
	3,000	200
18,000	10,000	11,500-11,000
	6,000	6,300- 6,800
	3,000	200
20,000	10,000	12,000
	6,000	7,200
	3,000	800
22,800	10,000	12,000
	6,000	7,200
	3,000	3,600

¹ If two units are used run 6,000 at 200 kw.

Of next importance to providing proper instructions for handling various loads is the matter of seeing that the instructions are carried out intelligently. The officers of the company keep in touch with this situation through a system of daily power-house reports. In addition to the usual data asked for on daily power-house reports, these reports call for the load curves from each of the plants, the total load curve and a graphical statement of the hours of operation and of each turbine and boiler unit. A part of one of these reports is reproduced herewith. The horizontal lines drawn through the load curves are the feature of the report. Each line, it may be observed, is opposite the designation of a turbine or boiler unit at the right margin of the page. The length and position of these lines indicate what machines were used at each hour, and also show in definite relation to the load curve how accurately instructions have been carried out. The lines used to show boiler operation also show whether the boiler was steaming or was banked.

B. J. Denman, president of the Moline-Rock Island Manufacturing Company, is a strong believer in the value of this method of charting operating methods. He has applied it in the past to other plants under his direction, and each time improved economy has resulted.

HOW TO REDUCE COST OF STATION REGULATOR

Conditions with the Dayton (Ohio) Power & Light Company made it seem necessary to regulate the voltage on circuits supplying station lighting in the new power house at Miller's Ford. To keep from buying a high-voltage regulator to operate at the generator potential of 6600 volts the scheme of connections illustrated here was worked out. From the 6600-volt bus these circuits were taken through the 200-kva., 6600/230 and 115-volt transformer which fed all station lighting circuits. In the outside lines of the three-wire secondary of this unit was connected a series boosting transformer with a ratio of ten to one, the high-voltage winding being designed for 230 volts and the low voltage for a total of 23 volts, 11.5 volts in each half. The high-voltage winding of the boosting transformer receives from 0 volt to 230 volts from one winding of a low voltage one-to-one ratio induction regulator, the other winding of the regulator being energized

from the outside lines of the secondaries of the main 200-kva. transformer. Connections to the contact-making voltmeter as

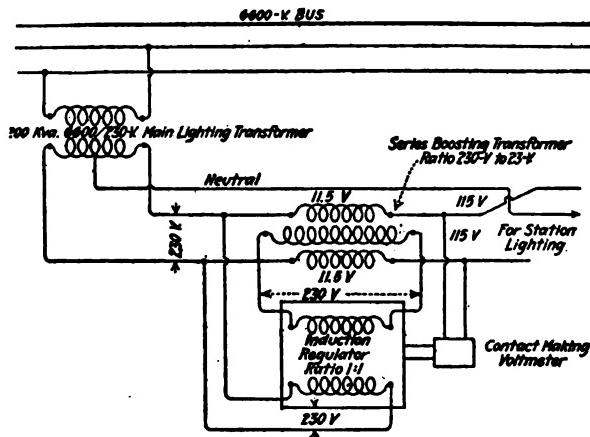


FIG. 29—REGULATOR ARRANGEMENTS MADE TO AVOID BUYING HIGH-VOLTAGE UNIT

shown completed the job. The unit is now operating satisfactorily.

TRACK SCALES SAVE THEIR COST IN VERY SHORT TIME

E. S. Hight of the Illinois Traction System, Peoria, Ill., which operates light and power properties in many cities in the Middle West, is a firm believer in the value of track scales for central-station companies. Several properties of this company have bought track scales and installed them at their plants. When a car of coal is received it is weighed before being dumped. If the track scales show that the car contains only 88,000 lb. (40,000 kg.) of coal, while the invoice shows that it contains 100,000 lb. (45,000 kg.), the central-station company pays for only 88,000 lb. (40,000 kg.) of coal. The money which it has saved through this process, Mr. Hight says, will soon pay the cost of the scales.

When this view was recently presented before the Iowa Section, National Electric Light Association, the question arose as to whether this plan should be employed where the contract which the central-station company had with its coal company specified

that the coal was to be paid for at "mine weight." Mr. Hight expressed the opinion that this provision in the contract carried little weight if the central-station company through the use of track scales showed that car weights were short. He said further that he believes no coal company would go into court with a case where accurate records kept by central-station companies showed that the weight of cars at the central station was less than it was represented to be at the mine.

TEAM SYSTEM IS THOUGHT TO BE BEST LABOR SOLUTION

Labor conditions affecting public utilities are as difficult at Youngstown, Ohio, as at any point in the country, according to H. W. Bromley, engineer of power production for the Mahoning & Shenango Railway & Light Company. As a result of this the company has come to the policy of paying wages as high as any of the neighboring industries, including the steel mills. Common labor, which two years ago was paid 17.5 cents an hour, is now getting 54 cents an hour. Watch engineers are being paid \$173.50 per month for nine-hour-a-day shifts; switchboard men receive 52 cents an hour and work nine hours; oilers and water tenders are paid 45 cents and 51 cents an hour respectively, and foremen are paid from 45 cents to 48 cents an hour. Besides being expensive, this labor is difficult to handle, and constant friction arises.

Bonus systems have been tried, but without success. The latest plan, and the one which seems to Mr. Bromley to be destined to give the best results, is one which he calls the team system. With this plan a foreman paid 70 cents an hour is placed in charge of five or six men. This unit is called a team. The foreman is held responsible for the quantity and quality of work done by the team as well as for destruction of material by its members. The teams are usually chosen so that all of the men in each unit, including the foreman, are of the same nationality. The real bosses of the job then talk to the foremen, but never to the men. This plan gives the foreman a good opportunity to keep in close touch with all members of his team and to bring out their best efforts. Of all the groups employed under this system negroes are said to have accomplished the best results.

A PLACE FOR GAS ENGINES

In many electric service systems there are frequency changers or synchronous condensers at various points that might be utilized to help carry increased loads without much additional investment, says Henry M. Trench, a construction engineer. Since these units are usually situated at the tie-in points between systems or at centers of distribution, the conditions are almost ideal for their operation as generators. To permit this little additional equipment is needed besides some internal-combustion engines (gas or oil, depending on which is more convenient to use) to drive the units.

Where such machines are installed a clutch or other mechanical connection may be inserted between them and the internal-combustion engine so that they may be engaged or disengaged as conditions require. With this arrangement the units may be used for their original purpose or as generators whenever desired. The engine attached to a motor-generator should be rated at the combined capacities of the motor and generator so that both may be driven as generators. Starting of such reserve plants could be made automatic if desired, since power would always be available to start the outfits from the generator end.

SECTION II

THE SYSTEM

ECONOMY IN ELECTRICAL DISTRIBUTION

IN order to get the maximum use from existing apparatus greater effort must be made to study the losses in distribution and to reduce them by the best means, writes W. B. Stelzner. When automatic voltage regulators are used on lighting feeders, for instance, it may be possible to open the primary circuits during the light load period and thus save 75 per cent of the iron loss.

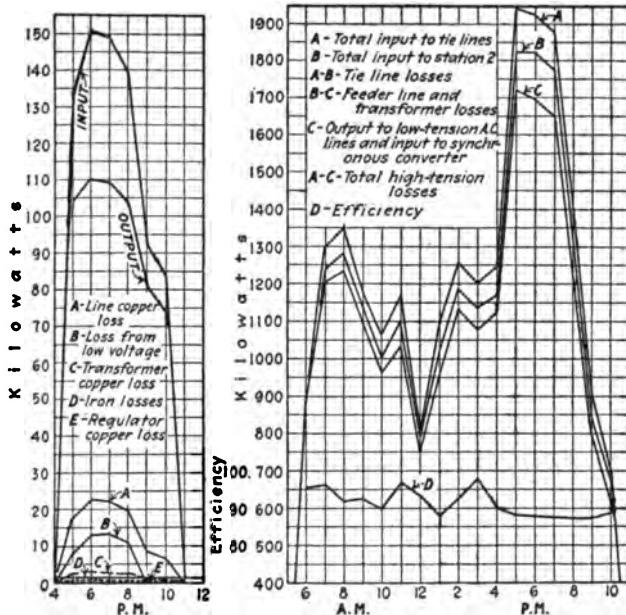
It is generally known if the primary lines of a distribution system are too small an excessive copper loss results, but it is not so well understood that if the voltage at the load is low the power is correspondingly decreased and a definite loss of revenue occurs. Larger conductors are thus required. In the case of low-tension circuits, however, line losses may often be reduced and the service improved by changing the transformer locations. Another serious obstacle to economical distribution is low power factor at the load, which causes high line losses and seriously limits the capacity of the wires. This condition may usually be attributed to the operation of induction motors on the system at only partial load, and is obviously best corrected by rearrangement of the motors or if this is not feasible by the use of synchronous motors.

An analysis of the losses on the lines of a company of medium size was recently made and some of the results are here reviewed in order to show the economic importance of these losses in the distribution of electricity. The losses that will be discussed are: the high-tension-line copper loss, the low-tension-line copper loss, the induction regulator losses and the transformer losses. The copper losses will apply to the conditions obtaining for the average winter load.

The system studied includes a generating station connected by four lines to a substation from which emanate three lighting feeders and one power feeder. These feeders are equipped with sin-

gle-phase regulators and supply current at approximately 2400 volts. A synchronous converter also supplies a railway load from the substation.

High-Tension-Line Copper Loss. The high-tension-line copper loss is given in Fig. 30, which shows the condition existing in one of the lighting feeders. The curves show this loss to be 98 kw.-hr. for a twenty-four-hour period, or 16.6 per cent of the



FIGS. 30 AND 31—LOSS CURVES FOR SINGLE-PHASE FEEDER AND EFFICIENCY OF HIGH-TENSION SYSTEM

Maximum copper loss occurs at peak load and may thus limit rating of line. Iron losses are ever present, however.

energy sold in the same time. This large line loss is accompanied by an excessive pressure drop with the result that the pressure at the load is below normal and a direct loss in the sale of energy ensues. When the load current is 51 amp., the regulator reaches the position of maximum boost and any increase in load current produces a fall of voltage, entailing a loss of revenue.

In this case the obvious remedy is to increase the size of wire in order to reduce the line drop sufficiently to permit the induction regulator to hold the voltage up to normal. The loss of

energy may be calculated at the rate of 7 cents per kilowatt-hour, assuming that the added cost of supplying this energy would be small. As will be noticed, the line copper loss is appreciable only between 5 and 10 o'clock in the evening. Although this loss occurs at the peak load, a possible minimum value for the loss, the cost of coal, might be 0.5 cent per kilowatt-hour. Using pre-war prices for material and labor and an annual charge of 10 per cent for interest, depreciation, insurance and taxes, the saving by replacing the No. 6 wire used with No. 2 is as follows:

No. 6 B. & S. Wire	No. 2 B. & S. Wire
Cost of wire as installed to point <i>a</i> ; Fig. 5.....\$239.00	Cost of wire .....\$602.00
	Changing wires 80.00

	\$682.00
	Credit for removed wire.... 75.00

	Cost of change .....\$607.00
24-hr. capital charge ..... .06	.17
24-hr. cost of line loss..... .49	.19
24-hr. loss due to low voltage 3.36	.00
_____	_____
Total 24-hr. charge..... \$3.91	\$0.36

The calculations indicating the economy resulting from the selection of a No. 2 wire for this circuit are summarized in the following tabulation:

Wire Size, B. & S. Gage	4	2	1/0	2/0	3/0	4/0
Additional capital required for						
change to above wire size..	\$385	\$607	\$985	\$1,235	\$1,545	\$1,955
Total twenty-four-hour charge	\$0.40	\$0.36	\$0.40	\$0.43	\$0.49	\$0.60

The No. 2 wire carries the smallest charge and the capital expenditure required in its installation will be recovered within one year's time owing to the decrease in operating costs. The economy resulting from the substitution of the larger wire is very evident.

Low-Tension-Line Copper Loss. The low-tension-line drop is probably the most important element in maintaining a high standard of service. This is apparent when it is considered that by means of voltage and power-factor regulators the pressure of the high-tension lines can be controlled. With a well-designed system and under efficient operation these regulators give practically constant voltage at the distributing centers. Es-

pecially is this true when lighting feeders are maintained separate from the power feeders. Such apparatus is not used on the low-tension lines and the regulation at the loads is therefore determined almost altogether by the low-tension-line drop.

The line losses in the low-tension circuit are indicated in Fig. 32.

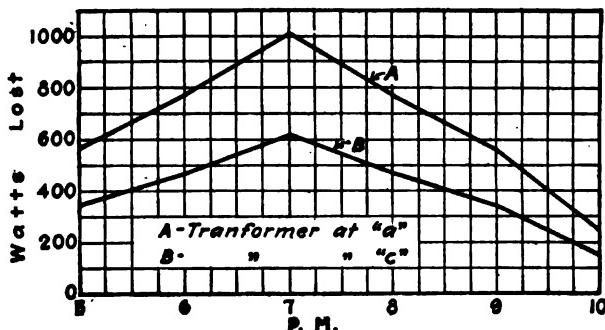


FIG. 32—LOW-TENSION-LINE LOSS

Curve A for the circuit shown in Fig. 34 with transformer at *a*; curve B with transformer at *c*.

32. These data give the copper loss in the line wires and service leads and show the influence on the losses of the design of the circuit. The information may also be presented as follows:

	Curve A	Curve B
Transformer size (kva.)	20	20
Energy sold (kw.-hr.)	90.7	90.7
Line loss (kw.-hr.)	3.94	2.39
Per cent lost	4.2	2.6

A comparison of curves A and B indicates which is the most economical location for the transformer feed-in point. This is a most important consideration both with regard to the losses and to the regulation at the loads. The cost of moving this transformer to the position indicated would be \$5.50, a sum fully warranted in view of the improvement in losses and regulation. A further change that might be warranted would be to change the size of wires *ab* and *bc*. In some cases other considerations may govern the selection of the transformer location, and position *a*, Fig. 34 may be chosen. In this event the change in wire sizes must be made or the circuit may be sectionalized and another transformer installed.

Power Factor. The power factor of a circuit depends not

only upon its characteristics but those of the apparatus connected to it. To transmit 100 kw. at 2400 volts single-phase would require a line current of 41.6 amp. if the power factor is unity, and a current of 52 amp. if the power factor is 0.80. Due to this increased current at reduced power factor, the copper loss in apparatus and lines is increased in proportion to the square of the decrease in the power factor. Low power factors, therefore, mean greater losses, lower capacity and decreased economy in distribution. The power factor of a circuit may be changed by a rearrangement of motors and loads, so that all induction motors will be operating under approximately normal load conditions, or synchronous machines may be used of sufficient rating to control the power factor of the circuit.

For the circuits involved in this study the power factor of the lighting feeders averaged 0.92 at peak load and 0.42 at no load. The power feeder, owing to lightly loaded induction motors and transformers, had an average power factor of 0.52. The power factor of the tie lines was usually kept above 0.90 by over-excitation of the synchronous machine supplying the railway load.

Fig. 33 gives the loss in the tie lines for two loads, a day load and a night load, and shows how this loss would vary with the power factor. Suppose an induction motor-generator set were used in the substation and that this should result in a tie-line power factor of 0.85 for the night load and 0.70 for the day load. Then results would be as follows:

Time	Actual Loss (Kw.)	Assumed Power Factor	Loss Due to Resulting Reduced Power Factor	
			Loss (Kw.)	Power Factor (Kw.)
7 p. m.	108	0.85	141	33
10 a. m.	66	0.70	117	51

The reduction in line loss by power-factor correction, with its accompanying effects on the pressure regulation at the substation and on the capacity of the tie lines, measures the economic value of power-factor control and its influence in the selection of power equipment.

Voltage Regulation. Pressure regulation is involved in all distribution problems and it is an important factor in electric service. Good regulation means minimum losses and maximum sale of energy.

By separating the lighting and the power loads and supplying

them by different feeders, as is done in the system studied, individual control of each is possible and the best regulation may be secured. To accomplish this automatic voltage regulators are required for each circuit.

The fluctuating power loads produce power factor and current variations in the tie lines, and these two effects combined with

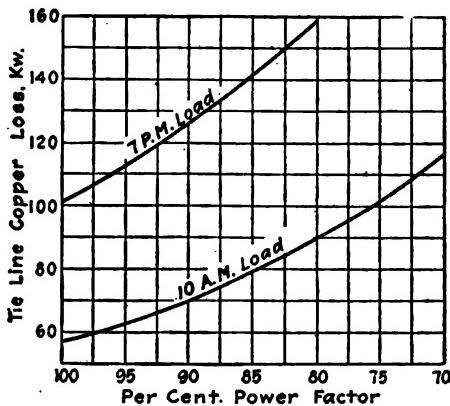


FIG. 33—VARIATION OF TIE-LINE LOSS WITH POWER FACTOR

variations in the generated voltage determine the fluctuations of the pressure at the substation bus. This pressure may be controlled by the use of an automatic voltage regulator in connection with the synchronous machine in the substation, as in this way the power factor may be held constant. A similar regulator, if required, installed at the power station would control the pressure generated there.

Induction Regulator Losses. The loss in energy sold due to low voltage at the load, as shown by Fig. 30, is caused by resistance of the line. The loss is kept as low as that given by means of the boosting action of the induction regulator, increasing the phase pressure from 2400 to 2600 volts. The influence of the regulator in controlling this loss is determined as follows:

Energy delivered to the circuit as installed (kw.-hr.)	757.8
Energy that would be delivered without regulator (kw.-hr.)	626.0
<hr/>	
Difference during the period of twenty-four hours (kw.-hr.)	131.8

This indicates the decided usefulness of the regulator even without considering its chief function of improving regulation.

The regulator which was under consideration was rated at 11.5 kw., 2200 volts, 50-amp. secondary. It was an old design with a tested iron loss of 400 watts and a copper loss at rated load of 187 watts. The high iron loss is partly due to the fact that it is subjected to a pressure 9.1 per cent in excess of that for which it

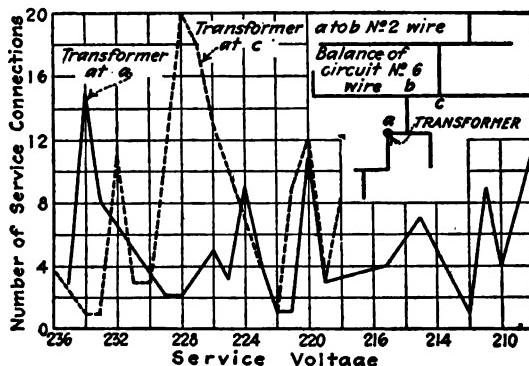


FIG. 34—VOLTAGE AT SERVICE CONNECTIONS

Full line shows number of services receiving a given voltage at peak load. Dotted line shows the improvement resulting from moving transformer from *a* to *c*.

was designed. The exciting current was found to be 2 amp. For a regulator of modern design the iron loss would be about 160 watts and the exciting current 1.89 amp.

A comparison of the losses for a year's time gives the following results:

	Old Regulator	New Regulator
Annual cost of iron loss	\$17.51	\$6.57
Annual cost of copper loss	2.61	4.53
Total annual loss	\$20.12	\$11.10

or an annual saving in losses of \$9.02 in favor of the modern design. This saving alone, however, would not justify the increased capital expenditure required to make the change.

The greatest economy in this case would be realized by installing switches in the shunt coils of the regulators so they may be disconnected during the nineteen hours per day of light or no load. This would result in an annual saving in iron loss of \$13.75 per phase or \$41.25 per feeder. Assuming a three-pole switch, installed, to cost \$75 and an annual charge of 13 per cent,

we have an annual charge of \$9.75 on the switch. The net saving, if the switch is used, amounts to \$31.50 per feeder per year. The iron loss of all transformers on one circuit amounts to 1.2 kw. At a cost of 0.5 cent per kilowatt-hour the annual cost of this loss is \$52.60. With rated voltage at each transformer and with transformers of modern design the annual cost of the iron loss would be \$47.80, a saving of \$4.80 per year. Obviously this saving alone would not justify the replacement of these transformers with others of the proper voltage rating.

Summary of Losses. In order to show the relative magnitude of the losses as studied, the following table applying to one circuit is given for the twenty-four-hour period considered.

Transformer iron loss (kw.-hr.)	28.8
Regulator iron loss (kw.-hr.)	9.6
	<hr/>
Total iron loss (kw.-hr.)	38.4
Per cent of total loss	20
Transformer copper loss (kw.-hr.)	12.5
Regulator copper loss (kw.-hr.)	1.4
Line copper loss (kw.-hr.)	98.0
	<hr/>
Total (kw.-hr.)	111.9
	<hr/>
Per cent of total losses	56
Loss due to low voltage (kw.-hr.)	48.0
Per cent of total loss	24
Total loss (kw.-hr.)	198.3
Total input (kw.-hr.)	788.4
Total output to low-tension lines (kw.-hr.)	590.0
All-day efficiency, per cent	75

The total losses in the high-tension system are as follows:

	Kw.-hr.
Energy to tie lines	21,440
Energy to bus at substation	20,360
Loss in tie lines	1,080
Loss in feeders, regulators and transformers	1,114
Total loss	2,194

Conclusions. Knowledge of the actual losses and their distribution over the system is essential to the most economical operation. Such data show just where more copper is needed, where copper may be removed, where to install regulators and power-factor-correcting devices, the most economical location of transformers, etc. In other words, a knowledge of the distribu-

tion losses is necessary for the most effective use of the system or the production of maximum service at a minimum cost.

The line copper loss, since it varies with the square of the load current, is likely to be serious. The gradual growth in load may result in large line losses or changes in the distribution of the load may result in idle copper. A survey of the losses reveals these conditions and leads to their correction.

The iron losses are kept low on this system by reason of the fact that the transformers are so spaced as to supply rather large areas. In this way larger as well as fewer transformers are used with a resulting reduction of iron losses and exciting current. This practice also results in a lower investment in transformers. Another advantage lies in the fact that by supplying the larger area a reduction in transformer rating is possible because of the diversity factor of the connected load. In some cases, however, these economies may be more than offset by the losses in the low-tension lines. Economies can be obtained by using larger transformers and increasing the distance between them when such a policy is consistent with the investment carried in the low-tension mains.

Power-factor correction on lines carrying loads of low inherent power factor results in a material saving in line loss and line capacity and a decided improvement in regulation.

The value of a study of the losses encountered in the distribution of electricity is made apparent by considering the fact that the ultimate cost of the product depends on the efficiency of the system. High efficiency, though a desirable attribute, cannot always be fully realized if the system is to have its greatest value. Low capital cost is essential to low production cost and low capital costs are influenced by losses as well as by diversity, load factor, available funds, etc. On the other hand, a mistaken economy in capital costs may act to seriously impede the development of the system. While no system can be laid down as commercially complete, the engineer must look, although it may be far into the future, to what would probably be the demand if the whole energy consumption of the district were supplied electrically.

The rapid growth in the load so often experienced illustrates the necessity for a rather generous attitude on the part of the public toward the utility in order that this increase may be prop-

erly taken care of and the best interest of both public and company conserved.

TREND OF PRACTICE IN OVERHEAD DISTRIBUTION

In keeping with the spirit of the times, the transmission and distribution committee of the Ohio Electric Light Association has pointed out that the most important factor in distribution systems is the economical and efficient use of all apparatus and materials. This it is believed, would lead to a standardization of all materials. Usually a distribution system grows by the addition of transformers and secondaries. Then as the system expands it generally requires complete revision. The most noticeable condition is the great number of small transformers which have been installed. These should be replaced by several large transformers, of which the advantages are enumerated below:

1. The investment in transformers is less because of the smaller cost per kva. of the larger transformer.
2. The core loss is less and therefore the efficiency is greater.
3. The number of lightning arresters is reduced.
4. The transformer capacity might be reduced because of the greater diversity of load which occurs with the larger number of consumers supplied from a single transformer.
5. Transformers should be installed about 1700 ft. (518 m.) apart in residence sections to insure the economical use of a distribution system.

The secondary system should be rebuilt, using three-wire 230-volt circuits for all street mains. Great care must be exercised to provide a balanced condition of the load. The neutral wire in a balanced system may be two sizes smaller than the outside wires. The voltage drop of a balanced three-wire system is one-fourth that of a two-wire system, other conditions remaining the same in both systems.

ECONOMY OF WATER EFFECTED BY INTER-CONNECTION

It is well known that it is a business necessity for every electric power company to give special study to the finding of possible economies. In order that the greatest amount of conservation be

possible, it is essential, writes R. H. Halpenny, Electrical Engineer, Southern Sierras Power Company, that companies operating in the same or adjacent territory make a study of load conditions peculiar to each with a view toward determining what possible economical advantage is to be had by an interconnection of the systems. There are valleys in the daily load curve of the Nevada-California Power Company that allow the plants operating on that system to deliver 6000 kva. to the Southern Sierras Power Company system through the three-phase tie-in transformer, and to do this without the use of any greater quantity of water than that required by the Southern Sierras plants operating on the same stream.

When two or more companies make use of both hydro-electric and steam-electric generating plants it is often possible to profit by the dissimilarity in the load curves of each company to effect a saving in fuel by the more advantageous use of available excess hydro power resulting from an interconnection of the systems. By such interconnections of their systems various groups of power companies in this country have made possible the use of great quantities of coal and fuel oil for other purposes. A typical interconnected group is that of southern California. The magnitude of the resultant fuel conservation and the extensive character of the interconnection have been presented to the readers of the *Electrical World* in the interesting article of R. J. C. Wood in the issue of Aug. 24, 1918.

It is not the intention here to deal with the subject of fuel conservation as accomplished by the tying together of a number of large systems. It is proposed instead to describe an interconnection of two electrical systems that makes possible the greatest economy in the use of the same storage water by certain of the generating plants of both systems.

On a small stream on the eastern slope of the Sierra Nevada mountains the Nevada-California Power Company developed storage facilities and installed three hydroelectric plants during the period 1905 to 1908. Typical of many streams in the Sierra Nevada range this one, known as Bishop Creek, is served by a watershed of considerable area and has a rapid fall, dropping more than a mile (1.6 km.) in 14 miles (22 km.) of length. The area comprising the watershed is about 39 sq. miles (10,000 hectares) in extent and is made up of three separate run-off areas

from which issue the North, Middle and South Forks of the creek. Natural storage sites on the south and middle branches of the creek were utilized, and by the construction of dams a total storage capacity of 21,000 acre-feet (25,800,000 cu.m.) was developed.

The natural flow of the stream varies from 20 second-feet (0.6

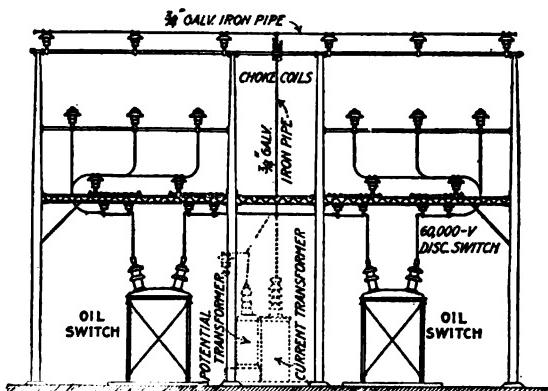


FIG. 35—CROSS SECTION OF OUTDOOR CONTROL SUBSTATION AT JUNCTION OF INTER-CONNECTED LINES

cu.m. per second) to 700 second-feet (20 cu.m. per second) at different seasons of the year, and it is evident from this that storage is essential for the continuous operation of generating plants; in fact, during four months in the year it is necessary to depend on storage water to a very large extent.

Two transmission lines were built into Nevada for the purpose of serving the mining district in and around Goldfield, Tonopah, Manhattan and other southern Nevada mining towns. This transmission system, with a mileage of 270 miles (430 km.), is of wood-pole construction and is operated at 55,000 volts "Y," with neutral solidly grounded at generating stations and substations.

Systems Interconnected. During the years 1912-1913 the Southern Sierras Power Company constructed two plants on Bishop Creek, making a total of five plants on the one stream. The erection of a double-circuit steel-tower line 239 miles (385 km.) in length and terminating to the south of San Bernardino, Cal., made possible the transmission of this additional power to an entirely different section of country from that served by the

Nevada-California Power Company, and permitted a more complete utilization of the power development.

The design of the tower line is such that operation at 140,000 volts "Y" is possible, although a transmission voltage of 87,000 volts was decided upon as best suited for the period during which a market for the power was being developed. At the time the line was put into service certain conditions made it desirable to operate it for a time at 55,000 volts and all transformers were accordingly provided with a 55,000-volt tap. By reason of the capacity in synchronous units available at the southern end of the line it has been possible to operate the line up to the present time at 55,000 volts with reasonably good voltage regulation. This synchronous capacity consists of generating units in the reserve steam plant at San Bernardino and synchronous condenser and frequency-changer sets at the end of some of the more important feeders leaving the San Bernardino station, making in all over 20,000 kva. capacity available for regulating purposes.

Since the Southern Sierras system has been operated at 55,000 volts delta and the Nevada-California system at 55,000 volts "Y," with grounded neutral, it was not considered advisable to operate the two systems as one because of the severe strain that would be imposed on the transformers of the "Y" system by a grounded condition of one of the line conductors, owing to the delta-connected transformers of the plants on the other system. In emergencies it has been necessary to switch one of the "Y"-connected plants to the delta-connected system, but this operating condition has been avoided as much as possible for the reason that a heavy ground on several occasions put one or more of the "Y"-connected transformers out of commission if the latter were operating on the delta system at the time.

It has already been stated that there are five plants on Bishop Creek. These plants are known as Nos. 2, 3, 4, 5 and 6, numbering down-stream. The wheels at No. 2 plant discharge into the intake of No. 3, which plant in turn discharges into the intake of plant No. 4, and in this way the water is not allowed to seek the natural channel or creek bed from the time it enters No. 2 intake until it is discharged from the tailrace of plant No. 6, from which point it is given over to irrigating purposes.

It will be evident from the foregoing that the greatest economy would result from the operation of the five plants in such a man-

ner that all the water passing through the wheels of one plant would in turn pass through each of the other plants. This is a condition that it is impossible to maintain with limited forebay capacity and varying loads on the different plants. The load curve of the Nevada-California Power Company systems differs materially from that of the Southern Sierras Power Company, and as a result the load demands on the individual plants do not occur at the same periods of the day. The load on the latter system has grown so rapidly that in spite of the addition of the recently completed Rush Creek plant with a capacity of 10,000 kw. it is necessary to make use of the steam reserve plant to handle the peak load. This condition makes it particularly desirable to have some means of connecting the plants operating on the two systems so that any excess capacity of the one group could be utilized by the other system, at the same time allowing

DATA ON BISHOP CREEK PLANTS OF INTERCONNECTED SYSTEMS

	Capacity, Kw.	Eleva- tion, Ft.	Static Head, Ft.	Effective Head, Ft.	Kw. per Sec.-Ft.
Plant No. 2.....	6,000	7,100	938	650	55
Plant No. 3.....	6,000	6,280	814	725	45
Plant No. 4.....	6,000	5,156	1,180	1,000	62
Plant No. 5.....	1,500	4,728	438	350	22
Plant No. 6.....	2,000	4,461	280	220	13

each plant to operate at a capacity determined by the amount of water passing through Plant No. 2, the plant furthest up stream.

On account of the undesirable condition resulting from a direct tying together of the two systems it was decided to connect the two by means of transformers, this being all the more necessary because of the fact that the voltage of the Southern Sierras system is to be raised to 87,000 volts within a few months. A three-phase, 6000-kva., 87,000-140,000/55,000-volt ("Y") General Electric transformer was recently installed for the purpose of tying the system together, it being the intention to install a second unit of the same capacity in the near future.

Location and Construction of Control Station. At a point near Plant No. 5 is the northern terminal of the tower line referred to above, and it is to this point that it is proposed to bring the lines from all of the hydroelectric plants in that district, making it a control switching station. This center is known as the control station, and it was the natural location for the installation of tie-in transformer equipment.

Plans for this station provide for two distinct parts, one to operate at 55,000 volts "Y" and the other at 87,0000 volts delta or 140,000 volts "Y." The 55,000-volt section has been partly completed, and a brief description will be given. The natural slope of the ground in that locality made it advisable to level off the required area in terraces, and these terraces form a natural division for the two parts of the station. On the upper terrace are the 55,000-volt bus structure and three-phase transformer.

Fig. 35 shows a cross section of the station and arrangement of equipment. Unit-type construction has been used, as is the practice of this company in building all of the more important stations. Latticed-steel columns form the upright members of the structure, while 2-in. (5-cm.) iron pipe serves as horizontal supports for the bus insulators and disconnecting switches. Each set of four posts forming one of the structural units is tied together with light fabricated beams, which also carry the pipe supports of the disconnecting switches. The bus is made of 1-in. (2.5-cm.) galvanized-iron pipe with $\frac{3}{4}$ -in. (1.8-cm.) iron pipe risers from disconnecting switches to bus. All of the pipe and steel frame is galvanized.

Plans for the completed station provide for two oil switches on each line, so that the lines can be readily transferred to either bus at will. These switches are equipped with remote control; in fact, all of the switches at this station, in both the 55,000-volt and the 87,000-volt sections, will be operated from a 110-volt direct-current bus supplied by storage battery.

The condition of the market at the present time as regards structural steel and electrical construction material has delayed the beginning of work on the new 87,000-volt section of the station. For the present the 87,000-volt lines will be connected to the 87,000-volt single bus of the older portion of the station. A temporary line on wooden poles will serve to connect this bus to the 6000-kva. transformer.

Saving Resulting from Interconnection. The installation of this transformer and the erection of the 55,000-volt section of the station were pushed as rapidly as possible in order to anticipate the seasonal increase of load in August and the months following on the system of the Southern Sierras Power Company. This accounts for the incomplete condition of that part of the station just installed, but does not decrease in any way the gain

in available power that the installation has made possible. The water required by the Southern Sierras company is thus used by the Nevada-California company to generate additional energy above its own load requirements, this excess energy being delivered to the former company through the 6000-kva. transformer installed for the purpose. The direct result of this is a saving in fuel oil that would otherwise have to be used in order to make up the power deficit on the Southern Sierras Power Company system. An additional advantage resulting from the inter-

MATERIAL REQUIRED FOR SIX-CIRCUIT STRUCTURE

Seven structural units.

Seventy-two 60,000-volt disconnecting switches.

Twelve three-pole remote-controlled 60,000-volt outdoor-type oil switches.

Eighteen dead-end fittings.

Eighteen $\frac{1}{2}$ -in. guy thimbles.

150 pin-type insulators and top clamps (for bus supports).

1,400 ft. $\frac{3}{4}$ -in. galvanized-iron pipe (for bus conductor).

550 ft. 1-in. galvanized-iron pipe (for bus conductor).

300 ft. $1\frac{1}{4}$ -in. galvanized-iron pipe (disconnecting switch supports).

1,750 ft. 2-in. galvanized-iron pipe (supports).

228 clamp tees.

Thirty clamp crosses.

156 high-tension cast pins.

112 U-bolts.

Sixty pipe caps.

connection is that both systems have practically acquired 6000 kva. or reserve capacity against the possible temporary loss of a generating unit or plant.

The mileage of the already extensive interconnected system of the southern California companies has also been increased by the addition of the Nevada-California system, which heretofore has had no physical connection with the group. The importance of this additional reserve capacity to all of the companies in the interconnected group has already been demonstrated. On the occasion of the loss of a large generating unit by one of the companies, the completion of the installation just described made it possible for some 5000 kw. to 6000 kw. to be delivered continuously to the company which was in need of assistance, and in this manner a serious power shortage was averted.

The installation of a large transformer in a locality removed some distance from the railway presented some difficulties in transportation and handling. The core of the 6000-kva. unit

weighed something more than 36,000 lb. (16,000 kg.), and in order that this piece could be hauled 15 miles (24 km.) over roads that are in only fair condition it was necessary to make a special rig so that the load could be distributed on two wagons, since no wagon in that district was capable of carrying the entire load.

In order to keep the center of gravity as low as possible the core was slung between two trussed beams. These beams were made up of cedar poles and two sawed timbers that were fortunately available. The wagons were trailers that had been used for tandem haul with tractors, and each had a capacity of 10 tons.

CHEAP WAY OF INCREASING LINE CAPACITY

To provide for growth in load the New York & Queens Electric Light & Power Company, Long Island City, N. Y., was confronted, not long ago, writes H. C. Dean, General Superintendent New York & Queens Electric Light & Power Company, with the problem of increasing the rating of its distribution circuits about 30 per cent. In some districts it was possible to postpone the installation of additional copper in the feeders and obtain the increase merely by replacing 100-amp. regulators in the substations with 150-amp. or 200-amp. regulators. In the case of the Long Island City district, however, the current-carrying capacity of both feeders and regulators had been reached, and all regulators were of the maximum size (200 amp.) which the company considers it desirable to use.

Choice of Systems. Three methods of solving the problem were open: (1) To install additional two-phase feeders (2300 volts, four-wire; (2) to install high-tension feeders and relieve the 2300-volt feeders of the larger consumers; (3) to change the 2300-volt, two-phase system to 2300/4000-Y volts, three-phase.

The chief question at first was whether or not it would be as cheap to change from two-phase to three-phase as to leave the two-phase system and transfer the larger consumers to lines operating at transmission voltage. A number of consumers are so supplied at the present time, and the company is looking forward to increasing such services to a large extent from now on. With the existing geographical layout of the lines and large consumers, the arguments were two to one in favor of changing the two-

phase distribution system. However, this was due to local conditions, and it is possible that for other companies the advantages would be materially different, either greater or less.

Careful estimates showed that the third alternative would provide the necessary rating for less than half the expenditure required by the other methods, owing chiefly to the high cost of copper. It had the additional advantage that any future feeders would have 50 per cent greater capacity as three-phase feeders than as two-phase feeders, while the per cent line loss and voltage drop would be only half as great. To determine the relative advantages of three-phase over two-phase, it was therefore only necessary to determine the valuation of the existing distribution system (less the poles) and to balance 50 per cent of this cost against the cost necessary to change to three-phase.

In the Long Island City district the power load is about four times as large as the lighting load, consequently considerable work had to be done in making changes in the transformer banks. Although new consumers are provided with three-phase service, it was decided to continue two-phase, 230-volt service to existing

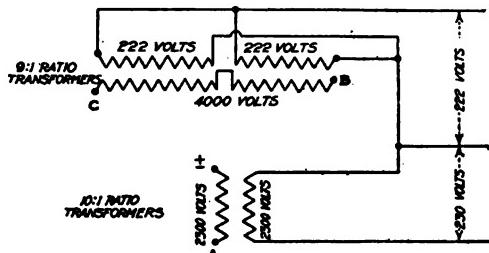


FIG. 36—METHOD OF SECURING CONVERTING FROM TWO TO THREE-PHASE WITH STANDARD TRANSFORMER

consumers. This made it necessary to replace one transformer of each power bank with two of half the rating having 10 per cent taps. The connections and the voltages obtained are shown in the accompanying diagram. There are no theoretical disadvantages in this method, as far as Mr. Dean can see, and it has given entire satisfaction for many months.

Method of Making Change-Over. To facilitate the work on the day when each feeder had to be changed from two-phase to three-phase (which in every case was Sunday), the replacement of one transformer in each power bank with two of half capacity

was made in advance, the two smaller transformers being connected in multiple temporarily. The testing of all underground 2300-volt services, the replacement of certain cable not safe enough for operation at 4000 volts, and the installation of pot-heads on all cable ends, constituted the only other preliminary work on the feeders themselves.

In the substation it was necessary to install a spare panel complete with equipment and three regulators for a three-phase

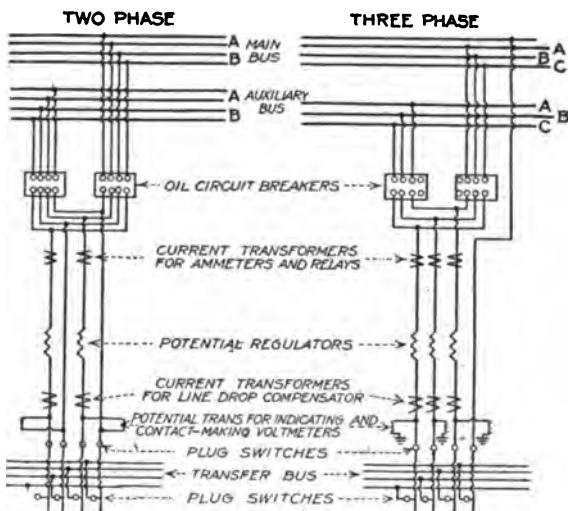


FIG. 37—METHOD OF ARRANGING FOR CHANGE-OVER FROM TWO-PHASE TO THREE-PHASE

feeder and to provide for maintaining one of the 2300-volt buses at three phase. This spare panel and equipment was used for the first feeder changed over to three-phase, which thus released a two-phase panel and the corresponding equipment. The panel in turn was built over to provide for the second three-phase feeder, etc.

On the day of actual change over of a feeder it was only necessary to change the connections of certain transformers and to transfer the feeder connections from the two-phase bus to the three-phase bus. Any power consumer who had to have service Sunday morning was permitted to use it until noon, by which time the fuse plugs of all power transformers were disconnected. The feeder was then switched from the two-phase bus to the

three-phase bus and the power consumers were given service in the order of their needs. The change did not require rearrangement of the overhead circuits.

Economic Advantages. The change from two-phase to three-phase distribution in Long Island City district has resulted in a very decided economy, since it has made unnecessary the installation of additional two-phase feeders, the expense of which would have been five times the cost of making the feeder changes to obtain three phase. Furthermore, it has decreased the line losses by approximately 200 kw., which alone would pay interest charges on the cost of making the change. In addition, it has improved the voltage regulation 100 per cent, which means that better service is given and that loads at great distances from the substation can be more economically handled than heretofore, thereby delaying the day when additional substations may be required.

RAISING THE VOLTAGE TO INCREASE LINE RATING

As a matter of economy and to conserve the use of material the Louisville Gas & Electric Company has reconstructed the distribution lines throughout the city, changing the voltage from 2300 to 4000 volts by connecting the transformers in "Y." This arrangement greatly increases the line rating with very small investment. A similar plan is being worked out for the heavy power lines, the voltage of which will be raised from 6600 to 13,200. The latter change will release considerable transformer equipment since the largest turbine in the generating plant is wound for 13,200 volts.

ECONOMY PROBLEMS IN NORTHWEST

In order to care for an increase of power load at minimum expense the Puget Sound Traction, Light & Power Company, Seattle, Wash., is taking advantage of the diversity of load between power customers on its 2200-volt lines. Several customers, formerly served by separate transformer banks, are now supplied from one set of transformers with a combined rating of 200 to 300 kw. Larger transformers with the same combined rating for-

merly required now serve an increased load. In the case of some large customers, service is given directly from the 13,800-volt feeders.

Rather extensive changes in the transmission system have resulted from the removal of lines which were not absolutely necessary, the equipment being used for new lines needed to serve industries essential to the war program. On the whole, about 20 miles (32 km.) of 55,000-volt line have been taken down and about 15 miles (24 km.) of new line have been erected with only a small amount of new material. At the same time the rating of the lines has been greatly increased.

It should be noted, also, that this company has found outdoor substations built upon four wooden poles the least expensive.

ECONOMICS OF POLE TIMBER

Thrift and economy have become national watchwords, but we seem to have overlooked the ever-present decay of poles at the ground line and annually renew millions of poles still sound and serviceable above the ground, according to Ernest F. Hartman, President, Carbolineum Wood Preserving Company, New York.

It is estimated that approximately 40,000,000 poles are in use to-day. Their value in 800,000 miles of lines has been fixed at \$400,000,000. As a general average the life of poles has been placed at ten years, making annual renewals cost in the neighborhood of \$40,000,000. On the basis of five poles per miles per annum for renewals, the drain on our forests will best explain the increasing cost of pole timber. While the treatment of poles before they are set is always to be recommended, this will not check the increasing consumption until a greater percentage are treated. At present only 25 per cent receive some kind of preservative treatment. Much can be accomplished in the way of more immediate saving by arresting the decay on poles already in service as hereinafter described. Such treatments will be a direct economy, as they save in the cost of poles as well as in the expense of resetting. It may also be taken into consideration that costs for line timber for some time after the war will remain at a very advanced level.

About eight years ago Mr. Hartman made his first experiments on arresting the decay of standing chestnut poles. An examina-

tion just made shows that these poles, whose ground-line circumference was greatly reduced in preparing them for treatment, are still perfectly sound. After making a thorough search of all the literature on pole preservation for data on arresting decay, the desirability of gathering reliable information based on practical experience was realized. Accordingly the methods described represent a correlation of the available experience. It is the object of this discussion to encourage extension of such forms of prolonging the life of poles to the millions actually in use.

Treatment of Poles. The decay of timber can be prevented, retarded and, what is more important, arrested. If the poles are sound at the ground line, no great difficulty will be experienced. In this case it is only a matter of opening up the ground around the poles to a depth of at least 2 ft. (0.6 m.), allowing the poles to dry out and, after cleaning the area to be treated, applying three hot brush coats or sprayings of preservative,¹ allowing just enough time between coats for the preservative to be absorbed by the wood. Treatment should extend 2 ft. (0.6 m.) above the ground line where the base of the pole is surrounded and shaded by vegetation. After filling in again one may rest assured that from five to eight years have been added to the life of the pole.

If decay has set in, then it becomes a question of the extent to which the pole has been weakened at the ground line. Varying with the extent of the decay one of the following forms of procedure will be found applicable:

When only the sapwood shows decay, open up the ground around poles to a depth of from 2 ft. to 3 ft. (0.6 m. to 0.9 m.), shave away all the decay and allow the poles to dry out. Scrape surface checks clean with a chisel or other sharp instrument. Brush the shaved surface with a flexible wire brush, after which apply three heavy brush coats or a spraying of heated preservative to the part at least 2 ft. (0.6 m.) above and 2 ft. below the ground line, allowing sufficient time between coats for the absorption of the preservative.

If the decay has gone beyond the sapwood and safety limits are not affected, it is recommended that the shaving away of the decay be followed with a heat treatment. Go over the shaved or scraped area with a plumber's torch and thus make certain that

¹ Where specific directions are given for the application of preservative these apply to the use of "Protexol" (formerly "Avenarius Carbofineum").

all wood-destroying organisms have been killed. A wire brush should be used to remove any charred wood. Then proceed with the application of preservative as before directed. Fill in with small stone (this will add a year or two to the life of the poles) or fresh ground, not sand. The old ground has in it the germs of decay and should not be used if the full benefits of the treatment are desired. Where poles show considerable checks at the ground line spray applications are preferable to the brush. An added life of five years can easily be secured.

JOINT USAGE OF POLES

Two or more lines of poles erected on the same side of the street or highway are not only unsightly but represent an economic loss and a waste of timber. Where the wires on such conflicting lines are carried at or near the same level a serious electrical hazard to persons or property is liable to be created owing to the proximity of the wires of different classes and the liability of contact between them or the possibility of employees working on one class of wires coming in contact with another.

The most practical way of eliminating the losses and hazards referred to in connection with lines located on the same side of the street appears to be a properly constructed joint-use line having a well-defined space for the wires and fixtures of each occupant, writes T. N. Bradshaw, chairman of committee which drafted Connecticut Rules on Joint Usage. These spaces should be separated from one another by an ample vertical clearance space. They should also be provided with a suitable climbing space so that employees of the various companies using the poles can ascend and descend them without coming in contact with the wires through which they may have to pass.

A wide experience covering a number of years with lines constructed as outlined above seems to indicate that the clearance space should be not less than 40 in. (102 cm.) vertically between signal wires and attachments and electric light or trolley-feed wires and attachments. Experience also shows that a climbing space of not less than 30 in. (76 cm.) wide on either the back or field side of the pole is necessary in order to provide for climbing and for the raising or lowering of transformers. It is, of course, preferable to provide a greater vertical separation than 40 in.

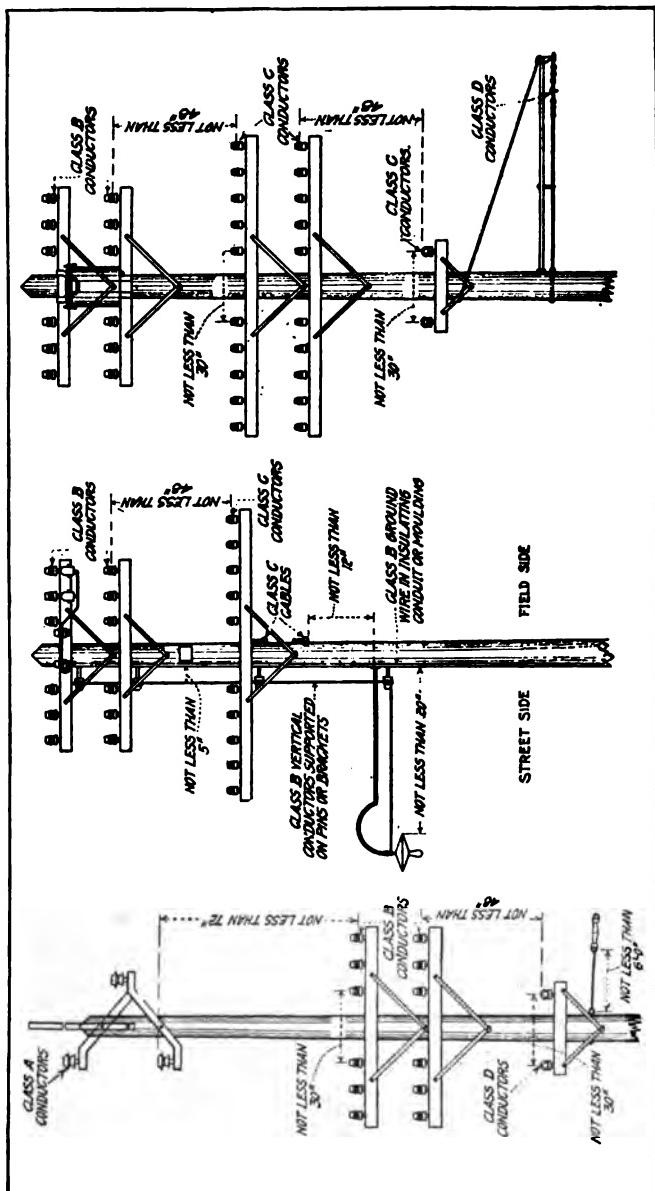


FIG. 38—RELATIVE POSITIONS OF POWER, SIGNAL AND TROLLEY WIRES ON JOINT POLES ADVOCATED BY CONNECTICUT COMMISSION

between signal wires and wires carrying high voltages, and many companies endeavor to have this space not less than 6 ft. (183 cm.) particularly with new lines, using the minimum clearance of 40 in. only on old lines that are made joint after the line has been in service for some length of time.

The street side of the poles should always be reserved for the vertical runs of the electric light or power wires, and the field side for the vertical runs of signal wires. Owing to the fact that there is no known protective device that can be placed on a signal circuit that will afford adequate protection against the potentials carried on high-tension circuits, it is not considered advisable to place telephone, fire-alarm or other signal circuits on the same poles with such circuits. High-tension lines should wherever practicable be constructed on rights-of-way remote from those occupied by the signal lines. (By high-tension circuits are meant the following: Constant-potential, alternating-current, neither side grounded, exceeding 5000 volts; constant-potential, alternating-current, one side or neutral grounded, exceeding 2900 volts to ground; constant-current, series-metallic, line current exceeding 7.5 amp., and constant-potential direct-current circuits including feeders and trolley-contact wires, one side grounded, exceeding 750 volts to ground.)

Pole lines located on the opposite sides of a street or highway are not considered as conflicting, but the same precautions should be observed, when erecting separate lines of poles, regarding the relative levels of the wires of different classes. That is, electric light or power wires should be carried on a taller pole line and the signal wires carried on a shorter pole line. This will enable electric light service wires crossing the streets to be carried over the telephone wires, and telephone wires from the opposite side of the street to be carried under the electric light wires. This practice prevents the interlacing of the service wires, which is liable to be a very serious problem in streets which are congested to any considerable degree.

In order to bring about the conditions outlined in the foregoing it is necessary to have some form of inter-company agreement covering not only specifications and methods of construction and the reservation of space requirements but also a fair division of the construction and maintenance costs. In Connecticut the matter is helped along by fair-minded legislation, and the Public Utilities Commission of Connecticut has promulgated

in its Order "D" docket,¹ No. 1447, a set of rules and specifications under which most of the wire-using companies of the state have been operating for some time with very satisfactory results.

Since most of the lines in Connecticut have been placed on a joint-use basis and the construction standardized there has been a marked decrease in the number of fatal accidents to the employees. This is undoubtedly due to the fact that employees working on signal circuits no longer have to climb through electric light wires in order to get at their own work, and the electric light wires are generally placed so far above the signal wires that electric light employees are not apt to come into contact with grounded lines of another class in working on high-voltage wires.

There is another feature which appears to make joint use preferable, particularly in cities and towns where there is considerable local distribution; that is, that the city or town is more completely covered by the pole lines of the two companies, and many companies have reasoned that it is better to own one-half of all the poles in a locality rather than to own all of one-half the poles.

In order to insure the success of any joint-line arrangement, particularly where electric light and signal lines are to occupy the same poles, the broadest possible coöperation must be indulged in between the various occupants for eliminating inductive interference. Electric light lines should always be kept free from grounds that might upset the electrostatic balance to ground, also long single-phase taps from three-phase circuits should be avoided wherever practicable. The voltage wave developed by the generators should be as free as possible from noise-producing harmonics, and consideration should be given this fact before the generating machinery is purchased from the manufacturer. Deviation from the pure sine wave should not be allowed to exceed the limit set by the American Institute of Electrical Engineers. These precautions are quite necessary in connection with electric light or power circuits, because it is not always possible to transpose telephone lines, for instance, so as to eliminate all inductive interference. In many instances it has been found necessary to place transpositions in the electric light or power circuits to coördinate with those in the telephone circuits.

¹ Can be obtained by addressing secretary of commission, Henry F. Billings, whose address is Hartford, Conn.

In Connecticut alone there are approximately 1700 miles (2700 km.) of pole lines used jointly by electric light and telephone or other signal lines. Practically all of this joint line mileage is standard as regards location of the wires and vertical or lateral separation, so that it is fair to say that the joint-use line is, under proper regulation, a success, simplifies the distribution problem and works toward safety.

While it is sometimes more expensive to erect a joint line, the cost to each occupant is usually less than a separate line or poles would be. The maintenance costs are also less because of this division of the charges. The lines appear to stand up better under the influence of severe storms because of the fact that such joint-use networks are usually much better guyed or braced than a single line would be. Moreover, such lines receive more attention from the engineers in order to make them satisfactory to all parties concerned.

TRANSFORMER INSPECTION AN ECONOMIC MEASURE

Thorough inspection of all distribution transformers returned from the lines should be made before they are again issued for service, first to lessen the chance of failure after replacement on the lines, and second to minimize the labor required in making the installation. Chances of failure are decreased if transformers are issued thoroughly clean and dry and with leads and bushings intact. Moreover, it is evident that minor repairs and adjustments can be made better and cheaper in the shop than by the installation crew in the field.

Bushings Need Close Attention. Bushings should always be carefully examined, as they are a frequent cause of failure. This is particularly true of the higher voltage classes (11 kv. to 22 kv.) owing to their sizes and greater liability to breakage. A break is not always evident from a casual examination, and each bushing should be shaken to disclose any looseness. A broken or loose bushing, especially a primary bushing, should always be repaired before the transformer is again utilized, since it is almost certain to break down in wet weather and may, under certain conditions, cause a burn-out of the transformer windings.

As most bushings are broken in handling transformers after shipping crates have been removed, means should be provided

for protecting them. This is especially necessary with the corner bushings of the flaring petticoat type used in transformers designed for moderately high distribution voltages since the insulators project beyond the re-entrant corners in the case. Some companies provide wooden angles which are bolted to the hanger lugs and encircle the bushings, thus eliminating breakage when the transformer swings against an obstruction.

Although more liable to breakage, double petticoat bushings with long leakage surfaces and deep recesses seem to give better service than the straight or corrugated types. The recess seldom becomes entirely filled with oil and dust, regardless of how much the lead may siphon oil. Furthermore, leakage will not occur across the clean surface between the two parts of the shell. On the other hand, the cylindrical types, whether plain or corrugated, usually become coated with dust whenever there is any oil leakage, and breakdown often results.

In renewing bushings in any line of transformers advantage should be taken of the most recent designs that may be accommodated in the outlet holes. Thus it will be found that the early white cylindrical types may in some instances be replaced with corrugated brown glazed bushings, which, having a longer leakage surface, are less liable to break down.

It is important that bushings which are suitable for the service be chosen. Substitutions should not be made unless the new type is superior to the old. A full supply of spare bushings should be carried in stock so that makeshifts will be unnecessary. A blue-print schedule showing the catalog numbers of primary and secondary bushings required for each tank number should be prepared with the assistance of the manufacturers for each line of transformers handled. This will be found of service both in expediting purchases and in selecting repair parts from store-room stock.

When installing new bushings a grade of sealing compound such as is specially recommended by the manufacturers for this purpose should be used. All of the old compound should be removed before the new bushing is placed. If the bushing is of the type set in with babbitt (those inserted from the outside are usually set in with babbitt, paper lock washers or some similar device), this metal also should be completely removed. In chipping out old bushings and compound provision must be made

for catching the scraps to prevent their falling into the coils or bottom of the case. Bushings of the curved styles are best made up complete with leads before insertion in the transformers. The more simple styles, which are easily filled with compound, may be filled in place.

Heating Compound to Right Temperature. Care must be taken to heat the compound to the proper temperature before pouring; otherwise cracks will result. The entire corner of the case in which the bushing is placed should be heated so that the compound will not be chilled on striking the metal. To chill the compound will often result in a leak between it and the case. Much of the oil leakage which occurs around leads and bushings is not caused entirely by siphon action along or through the lead, but may be due to cracks between the bushing and the sealing cement or between the latter and the case. This leakage will not occur unless oil is slopped onto the compound, but it is practically impossible to avoid this in handling a filled transformer. To avoid leaks of this character, not only should hot compound be used, but the surface of the compound above the bushings should always slope in toward the center of the case. This can be effected by tilting the transformer while the compound is being poured as well as while it is hardening. Where the compound must be built up a temporary paper dam may be installed, and after the cement has set it can be removed. This scheme also makes it possible to raise the level of the cement above the top of the bushing so that the bushing and recess may be filled in one operation.

Bushings should be kept clean. It is a good plan to incorporate in all directions covering the installation of transformers a note to wipe bushings carefully after the transformer is in place. Most of the oil and dust which, if left on a bushing, are so likely to cause breakdown are accumulated during transportation from the store room to the job. If the bushings are cleaned after the transformer is hung, this cause of trouble is largely avoided. When transformer tanks are being painted care must be taken not to get paint on the bushings, as the rough paint surface will tend to gather dust. Bushings of the larger types should be wrapped with cloth or paper while cases are being painted.

How Trouble with Leads May Be Prevented. Next to bushings, leads require most frequent attention. They are often

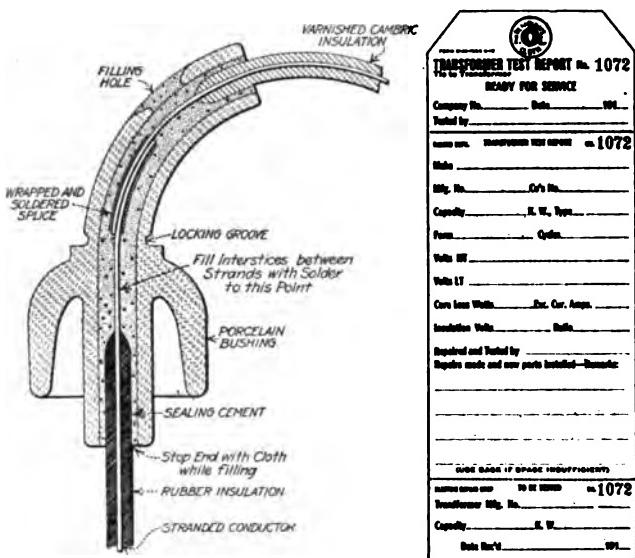
broken in handling or are cut short when transformers are removed. In addition, they deteriorate because of the siphoning of oil. Secondary leads of the types of transformers under discussion are invariably rubber-covered. Primary leads are usually rubber-covered, although some manufacturers have recently used varnished cambric insulation for voltages of 11 kv. and up. Each material has its advantages. Rubber withstands weather and moisture well, but it is deteriorated rapidly by oil. This weakness is its most serious defect as oil is often siphoned over the leads. Varnished cambric, on the other hand, while benefited by oil, does not withstand weather well when protected only by a braid covering. It is easily dried out by hot weather and is liable to absorb moisture in wet weather. These remarks apply, of course, only to the leads outside of the case; those inside are always insulated with varnished cambric.

In arranging for shop repairs to transformer leads it is first necessary to prepare a schedule of cables to be used in making renewals, in order to secure uniformity in purchases and repairs. This is preferable to attempting to replace the old lead with one precisely similar in size, insulation and stranding to that installed at the factory, since in the past manufacturers have differed considerably as to these details in transformers having identical ratings. To follow these deviations would require an unnecessarily elaborate stock of cable. A schedule which has proved satisfactory in practice is given herewith for two classes of transformers, for an 11,000-volt and a 2300-volt line. The cables selected, especially those used for primary leads, have not been chosen exclusively on a basis of their usefulness as transformer leads, but also with a view to their use in the wiring of substations and similar work, in order to avoid the carrying of overlapping stocks. All cables are specified as single-braid, rubber-covered. However, if any are to be used extensively in outdoor work, as for instance in wiring between cut-outs and transformers, they may be specified as single-braid and tape. The rubber insulation is 30 per cent Para for the 11-kv. leads and N. E. C. for the others.

It is evident that cable much smaller than No. 6 might be used for the smaller sizes of 11-kv. transformers. However, the expensive part of cable is the insulation, therefore little saving per foot can be effected by ordering a smaller size. Since this size is

used extensively in transformer installation wiring, short pieces are usually available for leads which might otherwise be wasted.

The greatest difficulty in installing leads is to prevent the siphoning of the oil. If this happens, the oil will rapidly deteriorate the rubber of the leads and in addition will gather dirt on leads and bushings and thus increase the danger of breakdown.



Figs. 39 AND 40—BUSHING CONSTRUCTION THAT PREVENTS SIPHONING; THREE-PART TRANSFORMER TEST REPORT

Where the primary terminal blocks are under oil, as is the case in most recent types of transformers, solid conductors may be inserted between terminal block and busing to prevent the siphoning which would be caused if stranded leads were used. Where stranded conductors are used the splice between the inside portion of the lead (which is insulated with varnished cambric) and the outside rubber-insulated part, as well as all interstices between strands for a short distance on each side of the splice, should be thoroughly filled with solder.

The splice in primary leads should be placed so as to be completely surrounded by sealing compound, and the short, bare and solder-filled portions on each side of the splice should likewise be covered (Fig. 39). A wrapped splice is generally used. Sec-

ondary splices and some of the simpler primary splices are placed above the compound. The varnished-cambric insulation of the secondary should be started above the oil level. After filling a bushing with compound, tape should be wrapped around the outgoing lead at the point where it leaves the bushing to prevent the compound from running out before it has set. After the cement has hardened this tape should be removed; otherwise all the oil which may leak between lead and compound will gather at this point and rapidly eat away the insulation.

Instructions should be issued to line crews cautioning them against handling transformers by the leads. Transformers are frequently dragged along the ground or truck bed by the leads or are kept from swinging into the pole when being raised by lines attached to the leads. This practice results in many broken leads and bushings.

When new leads are installed they should be made long. In some types of pole installations one additional foot of primary lead will permit direct insertion of the lead into the primary cut-out without a splice.

Some line foremen make use of the connectors provided on the leads by manufacturers, and use care in handling them; others appear to consider them superfluous and often cut them off. Instructions should be given to use these whenever present, as they are considerable labor savers, especially in the larger sizes, and will give no trouble if properly installed. Any connectors which are not used should be left taped to one of the leads so that they will be available if necessary in some future installation. In removing transformers foremen should be cautioned to cut the feeds between the connectors and the line and not the leads between the connectors and the transformers. The connectors may then be saved in the shop. Many leads are cut so short through carelessness that they must be replaced before the transformer can be reissued for service.

Painting of Cases and Care of Oil. Cases should be repainted whenever transformers are brought in from the lines, unless they have been installed only a short time. Sheet-steel cases especially will deteriorate rapidly unless protected by paint and if rusted should be given two coats. Before paint is applied it is necessary to clean the case thoroughly with distillate and a steel-wire brush to remove all dirt and oil. A good quality of turpen-

tine asphaltum paint will be found serviceable for this work. If a system of company numbers is in use, numbers should be re-stenciled on transformer cases as soon as they are slightly obliterated. A white-lead and linseed-oil paint should be used for this purpose. Stencils $2\frac{1}{2}$ in. (6.35 cm.) high may be readily deciphered from the ground, still they are small enough so that four or five figures may be placed on the smaller-size cases.

If the transformer has been installed for several years, it is preferable to draw off the oil for testing and treatment as soon as it arrives on the testing platform. On the other hand, if the transformer has been on the lines only a short time and the oil seems clear and without a burned odor, it need not be removed. In the case of the larger sizes of distribution transformers, a sample should be drawn from the bottom of the case with a "sneak" for a moisture test. All transformer oil should be carefully tested, handled and stored in accordance with the recommendations¹ of the apparatus committee of the National Electric Light Association. Linemen cannot be cautioned too often against handling oil in the open in damp or foggy weather. Companies utilizing distribution transformers of two voltages, as, for instance, 13,200-volt and 2300-volt equipment, will do well to reserve new oil for the higher-voltage equipment and use the second-hand treated and filtered oil in the lower-voltage apparatus.

When possible, transformers should be filled with oil before they leave the storeyard; this, however, is not always possible. If the old oil is not removed when transformers are returned from the lines, an inspection should be made to see that the oil is up to the proper level. Schedules of transformers showing tank symbols and quantity of oil required for each line of transformers in service should be readily available. It should be noted that transformers of the same make and type but of different form may require quite different quantities of oil.

Cleaning of Transformers and Detection of Flaws. The cleaning of the coils of transformers removed from the lines requires careful consideration, especially if they have been installed a considerable time and sludge has been precipitated by the oil. The elimination of oil deposits from the circulating

¹ *Proceedings N. E. L. A., 1917, Technical and Hydroelectric Section, page 281. Also available in booklet form.*

ducts is particularly essential since their effects are cumulative. By impeding the oil circulation they cause the transformer to overheat with a given load, which in turn increases the sediment. An air-transil-oil spray is effective in flushing the ducts. When the oil is drained off it will also clear any moisture which may be present at the bottom of the case.

Many transformers cannot be properly cleaned without removing the coils from the case; this is especially true where the sediment has thickened. Some of the older types of transformers which have no oil ducts between coils should always be removed and cleaned by scraping, as a thick coating is generally to be found on the coils caused by the lack of circulation. Care must be used in scraping to avoid damaging the insulation. An air-distillate spray will be found effective for this kind of cleaning, but should not be used unless the transformer is dried out before being placed in service. A distillate spray should not be used within the test room, owing to the fire risk. A cast-iron grating with removable containers should be provided on the transformer platform for draining coils and cases; otherwise oil will be scattered about the place. By this means considerable oil or distillate can be saved, as the oil can be filtered for re-use.

Cases should be examined for leaks. A crack in a cover may permit the entrance of sufficient moisture to cause breakdown. Cast-iron cases when cracked may be welded with an oxy-acetylene torch; sheet-steel cases may be repaired by brazing or welding. Drain plugs should also be examined and set in with red lead if leaky. Felt strips should be carried in stock so that when those in service are lost or worn they may be replaced. It is important that these be kept effective.

Hanger irons and lugs should be examined for cracks and flaws. When transformers are returned from the lines it is advisable to arrange some system by which the hangers are kept with them or properly marked so that they cannot be mixed with others. If an improper hanger iron is shipped unnoticed with the transformer, it may cause an expensive delay to the line crew.

If a transformer has taps, connecting lugs, nuts and bars should be checked for missing parts. If they are missing, they will usually be found in the bottom of the case, where they were dropped while taps were being changed in the field. Spare connecting links should be taped to leads.

It should be ascertained that coils and core are firmly held in place by the bolts and wedges. To send a transformer out loose in the case will often result in damage to coils and consequent breakdown.

Testing for Burn-Outs. The most difficult of all repairs are those to coils. When a transformer comes in which is suspected

SCHEDULE OF CABLES TO USE IN RENEWING TRANSFORMER LEADS
PRIMARY LEADS

Class	Transformer Size (Kva.)	Size of Lead	Insula-tion (1/64ths of In.)	No. of Strands	
11,000-volt 2,300-volt	1 to 100	6	16	7	
	1 to 5	12	8	7	
	7½ and 10	10	8	7	
	15 and 20	8	8	7	
	25 and 30	6	8	7	
	37½ and 50	4	8	7	
	75	2	8	19	
	100	1-0	8	19	
SECONDARY LEADS					
460-230-115-volt	1 to 3	8	3	7	
	5	6	4	7	
	7½ and 10	4	4	7	
	15	2	4	19	
	20 and 25	1-0	5	19	
	30	2-0	5	37	
	37½ and 50	4-0	5	37	
	75	400,000 c.m.	6	37	
2300-460-volt	100	500,000 c.m.	6	61	
	SECONDARY LEADS				
	1 to 20	6	8	7	
	25 and 30	4	8	7	
	37½	2	8	19	
	50	1-0	8	19	
	75	2-0	8	37	
	100	4-0	8	37	

of being burned out, unless it is evident from a superficial examination that the coils are completely ruined, tests should be applied with caution. A breakdown insulation test should never be applied until a megger is used. A premature insulation test may injure a transformer beyond repair. If the megger shows the insulation to be in bad condition, the transformer should be dried out by one of the usual methods and the test repeated. Such a dry-out will often correct the difficulty. Often a careful examination of the coils will reveal only a few damaged turns; these

may be replaced or reinsulated if carefully handled. If necessary, all coils should be disconnected so that each may be "meggered" to the core separately. The megger test is of course a preliminary step only for the purpose of trouble location. No transformer should be reinstalled which cannot withstand an appropriate insulation test. Ratio, core loss and exciting-current determination should also be made on each transformer before it is considered ready.

When it has finally been proved that a transformer is burned out it becomes necessary to decide upon its disposal. Several courses are open: It may be scrapped; it may be returned to the manufacturer on some exchange proposition; new coils may be wound in the local shop, or coils may be ordered from the manufacturer. In any case the decision will largely depend on the voltage class of the transformer, its age and type. Antiquated types having operating characteristics inferior to those of modern transformers should seldom be rewound. Transformers of the 2300-volt class can usually be returned to manufacturers for credit on a basis that is more economical than rewinding. On the other hand, it pays to order new factory-made coils for the higher-voltage classes. If a factory repair shop is available within reasonable distance, it may be cheaper to have the factory make complete repairs. When the coils are installed in a local shop, care must be taken to shellac and dry them thoroughly. Some form of drying oven should be available, and the transformer should be placed therein at a temperature of about 85 deg. C. (185 deg. Fahr.) for at least twenty-four hours.

Transformers should be stored in such a manner that they will be easily accessible. If platforms rather than racks are used, ample aisles should be provided between rows to avoid breakage of bushings. Besides, transformers of similar ratings should be grouped together. Burned-out transformers awaiting disposition should not be mixed with the others, and to eliminate any chance of their being taken out by a repair crew in an emergency they should be given a dash of colored paint or otherwise conspicuously marked.

Some recording system should be adopted in order that transformers returned from the lines shall be assured of proper attention and that no transformer shall be taken out until it is inspected and repaired if necessary. The three-part linen tag

(Fig. 40) has been successfully used by one company for this purpose. Upon arrival the yard foreman issues a tag for each transformer. The lowest section is torn off and sent to the shop as a notification of work to be done; the remainder is attached to the transformer. When inspection, repairs and test are completed the middle section is torn off and sent to the record department as a notification of work done, and also that the transformer may be again placed on the active list. The upper portion of the tag remains attached to the transformer until it is reinstalled. The condition of each tag shows at all times the status of the transformer to which it is attached, and regardless of the method pursued in ordering out transformers for use, no transformer will be taken which has not received attention.

USE OF METERING EQUIPMENT SAVES TRANSFORMER PURCHASE

Striving toward conservation of essential materials in accord with the spirit of the times, the Plymouth (Ind.) Electric Light & Power Company recently worked out a scheme for utilizing existing transformers more efficiently and thus avoided purchasing additional units. In general the plan consisted simply of making load measurements on certain transformers to ascertain what units could be relocated to better advantage as regards their capacities. The apparatus used in making the measurements consisted of two sets of current transformers and one graphic meter. One set of transformers were rated at 160/5 amp., 2500 volts each, and the other at 20/5 amp., 2500 volts each. The meter was a Westinghouse type U, with an eight-day clock and a 5-amp. scale. This equipment was all placed in a single box in such fashion that several desirable circuit changes could be made on a plug board constructed as a part of the outfit. These circuit combinations made it possible to use the metering outfit and get proper scale deflections on the meter on transformers between 10 kw. and 60 kw. A two to one ratio instrument transformer was used on smaller units.

When a test was made the metering outfit was hung on a pole at the transformer bank. In residential districts the duration of these tests was usually from Monday until Thursday and in the business districts was usually from Friday until Monday. On

motor installations records over a two-week period were sometimes taken.

As the result of forty such tests the locations of ten transformers were changed. In general it was found that units in residential districts could serve wider territory and thus release transformers to be removed to the business district, where most of the existing equipment was overloaded. Making the changes which were indicated to be possible by the tests has relieved the company for the time being of the necessity of buying transformers and has bettered the voltage regulation of the system as a whole.

DUCT SPLICING SAVES SHORT LENGTHS OF CABLE

The financial loss due to inability to utilize short lengths of cable is a serious one to all companies operating underground systems of distribution. These lengths are constantly accumulating owing to withdrawal of old cable necessitated by changes and replacements of existing circuits. Large companies doing a great deal of underground work keep these lengths and eventually can utilize them by matching in with new construction, but this involves keeping on hand a large quantity of slow-moving stock, tying up investment and often using valuable space for storage. Smaller companies usually are obliged to scrap their short pieces of cable, often at only a fraction of the original cost.

It has long been the practice to splice the shorter lengths of small cables, such as arc-light and main cables, to make up lengths that could be used, but a joint such as is usually made in large high-tension and low-tension feeders would be too big to draw into the standard-sized duct. It has doubtless occurred to many underground superintendents, however, that if a small enough splice could be made in such feeders much of this slow-moving or waste cable could be utilized. This possibility is of especial interest at the present time owing to the high cost of metals, difficulty in obtaining cable deliveries and desirability of releasing as far as possible the full capacity of the cable factories for the manufacture of materials directly useful in the prosecution of the war. In view of these facts the long experience of one of the large lighting companies in the development and use of duct splicing may be of interest.

How Splice Diameter Is Minimized. The underground de-

partment of the New York Edison Company, J. B. Noe and A. Rabe write, made such a splice in November, 1904, joining two sections of three-conductor, 250,000-circ. mil., 6600-volt cable. The diameter of the splice was kept down by staggering the joints in the three conductors, making a joint 24 in. (71 cm.) long, over which was placed a split lead sleeve slightly larger than the original cable, soldered at the seam and wiped to the cable sheath at the ends. This joint was made by drawing in the first section, making the splice in the manhole, and then resuming the pulling, drawing the splice and second section on into the duct. This original duct splice remained in service without failure for several years and when finally withdrawn for some cable changes was opened and found perfect.

Prior to 1911 no great difficulty was experienced by that company in utilizing short lengths of feeder cable, the large amount of construction work continually in progress providing a comparatively ready outlet for such material. In this year, however, the size of the standard high-tension feeder was increased from 250,000-circ. mil. round conductor to 350,000-circ. mil. sector, all new cable purchased being of the latter size. As a result large quantities of the smaller-size cable began to accumulate in the stockyard, it being impossible to match in the short lengths of old cable as parts of new feeders as had been the previous practice.

In the same year the proposed addition to the system of about twenty-five high-tension service connections offered a tempting opportunity for the use of this cable, provided that it could be spliced up to make such lengths as could be used in existing subway. Duct splices similar to the one made in 1904 were successfully utilized, and all these connections, involving the use of more than six miles (9.7 km.) of feeder, were made, using this old cable exclusively. Not one failure has ever occurred in any of these splices or on any of the more than 600 duct splices made on various cables.

During the next few years very extensive changes in the underground cable system due to starting up a new generating station provided an ample outlet for released cable, but in 1915, the accumulation of short lengths again becoming critical, serious attention was turned to the duct splice. Before adopting it as a permanent policy for all types of cables, tests were conducted to determine:

First—Mechanical strength, both of the spliced sleeve and the spliced conductor, as compared with the strain put on them in installing and withdrawing the cable under the severest duct conditions.

Second—Dielectric strength of the duct splice after it had been subjected to the strain of installation.

Third—Heating in the duct splice due to heavy loads.

All of these tests showed the duct splice as made up to be superior to the body of the cable.

A decided improvement was made at this time by "burning" on the lead sleeve instead of using solder. This made the joint as flexible as the rest of the cable, and as the spliced lengths could be put upon reels without fear of cracking, it became the practice to make the joints in the cable yard instead of in the man-hole, effecting a very great saving in cost. At odd times and on rainy days the short pieces were spliced up to make sections of such lengths as could be easily matched.

During 1916 a duct splice was developed for two-conductor, 1,000,000-circ. mil. low-tension concentric cable with three pressure wires. Large quantities of slow-moving stock of this type of cable were thus made available for immediate use.

Among the various types of cable on which the duct splice has been used, two deserving of special mention are triplex 350,000-circ. mil. 25,000-volt armored submarine cable and single-conductor 2,500,000-circ. mil. low-tension cable with pressure wires. Of the first type three 910-ft. (277-m.) reserve lengths were made available for immediate installation as four 610-ft. (186-m.) lengths by cutting and splicing. Of the latter type 2100 ft. (640 m.) left dead in the subways by the starting of a new substation were salvaged and are now installed as direct feeders to a new large customer.

Some idea of the amount of cable transformed from scrap or very slow-moving stock to actual service may be gained from the fact that the company previously referred to has to date a total of 211,569 ft. (approximately 64,460 m.) of duct-spliced cable of various types, representing a value of approximately \$380,000. Practically all of this material is now installed.

Splicing Done in Cable House. The work of making these special splices was at first done in the cable yard, temporary tarpaulin shelters being erected for protecting the exposed ends

of the cables from rain, snow or whatever necessary. As the work assumed larger proportions it was decided to erect a building with special facilities for handling the reels expeditiously and with a minimum of labor. A narrow-gage track enters this building from the point where the reels are delivered by truck and runs the entire length of one side. The reels are placed on small cars running along the track, from which they can be delivered to any of the six splicing stations. At each of these stations are two specially designed cable racks to hold the reels, the splicing being made between the racks. An electric motor with suitable speed control has been mounted on a car, and by means of a sprocket and chain connection can be used to reel or unreel cable of any of the racks. Only one man is required for this work instead of the usual gang of four or more. A convenient system of piping makes easy the connection of the oxy-acetylene outfits used for the lead burning at each of the splicing stations, thus avoiding a multiplicity of tanks.

Very little expense for material was incurred in the equipment of the splicing house. Much of it was rescued from the scrap heap, and some, such as the rails of the narrow-gage railway, was purchased from contractors at practically its scrap value.

While it would not be necessary for all companies using cable to prepare such an elaborate plant for duct splicing as the one described, it is obvious that all companies generally can adopt with great advantage the practice of making such duct splices to save considerable cable material that would otherwise be scrapped or kept in slow-moving storage.

CABLES COOLED BY FAN

Increasing loads on a cable duct line leaving the Dutch Point station of the Hartford (Conn.) Electric Light Company recently caused overheating, and to overcome this a motor-driven fan was installed. In this line there are nineteen occupied ducts carrying cables operating at 22,000, 11,000, 4800 and 2400 volts, and telephone lines of the company in addition. The duct runs underground from the plant to a manhole about 250 ft. (76.2 m.) distant, and the temperatures of the unoccupied sections were obtained by inserting maximum and minimum thermometers in a mandrel and pulling them through after sufficient exposure to running conditions. Air is circulated through the duct by a 30-

in. (76.1 cm.) fan-belt driven by a 5-hp. Westinghouse 220-volt induction motor mounted on the ceiling of the power-plant basement. An emergency connection is also provided so that the fan can be used to exhaust air or smoke from a transformer room below if necessary. By continuous operation of the fan the duct temperature was reduced from a maximum of 150 deg. Fahr. to 80 deg. Fahr. (71.1 to 26.7 deg. C.), thus enabling the cable line to carry an increased load for a given duct temperature and conserving copper.

TEACHING NEW MEN CABLE DUCT SPLICING

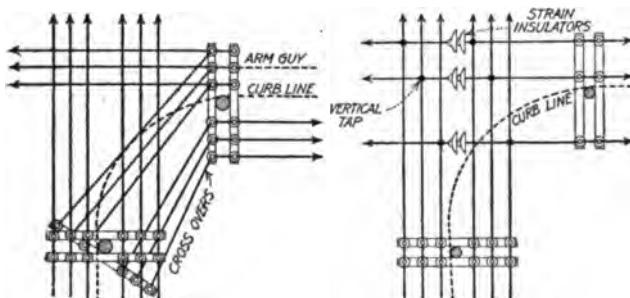
In order to be assured that new men are efficient and prepared to make good splices, the Duquesne Light Company of Pittsburgh, Pa., has arranged an imitation manhole in the underground department laboratory to allow the man to show his ability. This arrangement consists of half of a six-side manhole painted to appear like red brick and giving the man exactly the same amount of space as he would have if working under actual conditions. The work is watched by the superintendent or foreman of the underground department, and a man is not allowed to work in a manhole until he is fully qualified to make a neat splice and wipe the joint.

VERTICAL TAPS SIMPLIFY THE TURNING OF CORNERS

Corner work is often complicated and difficult to install with adequate clearance between wires in cities having wide curbs with rounded corners at street intersections. Single-pole buck-arm corners are generally impracticable even when side or alley arms are used, since the wires are brought too close to buildings thereby. Therefore a double-pole corner must be installed with connecting cross-overs run between poles. Vertical taps are sometimes employed rather than cross-overs as they give a neater installation. They are, however, more difficult to place, particularly where the poles are so high that the taps cannot be made from tower wagons.

A special installation in which considerable saving in first cost with added safety and simplicity was secured by means of verti-

cal taps and special line insulators is illustrated in the accompanying figures. In this case two independent 11-kv. circuits passed by a street intersection where it was desired to provide a branch from each circuit, one to the right, the other to the left.



Figs. 41 AND 42—OLD AND IMPROVED METHODS OF CONNECTING LINES RUNNING AT RIGHT ANGLES

The usual method of installing cross-overs would have required the construction shown in Fig. 41. Owing to the relatively high voltage of the circuits a 45-deg. buck-arm would have been required on the higher pole in order to secure proper clearances. However, by installing vertical taps and strain insulators as shown in Fig. 42, the construction was greatly simplified, both as to dead-ending and guying. Strain insulators were installed in pairs to secure an added factor of safety, although single units were sufficient for the voltage here employed. The insulators and taps are so placed that under normal operating conditions with both lines energized there is no potential across the insulators. The taps were installed by a lineman working from a temporary steel cable swung across the span.

HOW SYSTEM OPERATORS CAN IMPROVE ECONOMY

In order properly to conserve the energies and resources of a modern interconnected transmission system, made up of hydroelectric plants, steam plants and substations, the services of well-trained, competent load dispatchers or system operators are essential. Men of broad operating experience are needed for positions of this kind. They must be familiar, states Harry J. Burton of the Consumers' Power Company, Jackson, Mich., with the operation of steam plants, water plants and substations, and

with the care and maintenance of high-tension transmission lines.

System operators are in a particularly favorable position for observing the general status of an operating department, and with the guidance of their executives should be able to bring about successful and economical operation.

To operate to the best possible advantage the authority of the system operator should extend to the lines, stations and men, in maintaining the necessary operating conditions. Emphasis should be placed upon the importance of co-operation between all departments and the system operator. Pertinent information withheld from the system operator may result in serious loss to a company.

System operators should at all times be familiar with all the operating conditions existing at the various stations, substations and switching points. They should know the kind of coal used and the cost of it, unloaded, at the different steam plants. They should know the load at which the different generating units operate most efficiently, and the information they receive must be accurate if good and efficient work is to be done. They should be kept informed of the demands for power and of all changes in load as far in advance as possible, so that they can arrange to have different units placed in or out of service at the right time.

Responsibility of System Operator. Generating apparatus should not be placed in or out of service without the permission of the system operator, and on small systems boiler-room men should not be allowed to cut boilers in or out of service or to clean fires without his sanction. On larger systems he should at least know how many are available for service at all times. Boiler-room economy is of the utmost importance these days, and boilers should be operated at the most efficient load. Steam plants should not be run with more boilers in service than are actually needed; that is, ten boilers should not be fired when only eight are needed to carry the load. The load curve on steam plants should be straight for efficient and economical operation; that is, a good load factor should be maintained. Boilers can be prevented from "blowing off" during the noon hour and light-load periods by an intelligent handling of the water at hydroelectric plants.

System operators should aim to take care of peak loads with water power, and, as far as is practicable, water should be conserved for these periods. Sundays, holidays and other light-

load periods can often be taken care of by means of water power, thus affording an opportune time to inspect, clean and repair steam-plant equipment.

Hydroelectric Conditions and Coal Saving. Much energy can be conserved by a careful study of water conditions at the hydroelectric plants. The nature of the watershed, the amount and time of precipitation and the climatic conditions all affect operation, and some understanding of the flow and formation of a river is needed to know how soon or how much the pond would be affected after a given precipitation or thawing. The operation of floodgates should be checked up from time to time to see that they are in working order, as failure of these gates to work at a critical time may result in much damage and loss.

The determination of the most effective gate opening and the working of water down a river, through several water plants, as well as the handling of plants at times of low and high water, are economic problems that should be worked out so that, if possible, no water shall be wasted, the plants operated at the most effective head and a degree of protection maintained at all times. When extensive repairs to lines or equipment are contemplated, making it necessary to shut down a plant for a considerable period, the system operator should be informed as far in advance as possible so that he can arrange to use all the available water; thus as little as possible will be spilled while the repairs or changes are under way.

System operators should have sketches showing the high-tension wiring in all power stations, substations and switching houses and data showing pole numbers at the principal points along the lines, such as road crossings, trolley stops, telephone test stations and other items descriptive of the lines that would be of assistance in handling intelligently any case of line trouble that may develop. They should keep themselves informed as to the immediate whereabouts of patrolmen, linemen, repairmen and all superior officers, so that there will be no delay in securing help or advice in an emergency.

Competent line patrolmen are an invaluable help to the system operator, and reliable information received from them and acted upon may not only save equipment and prevent an interruption to service but may also eliminate a long period of inefficient operation. For example, a system operator may have planned to

use a certain line and plants to carry an important load, and owing to the failure of the line, or to trouble on it, he may be forced to use a line and plants less efficient, and in addition water may be wasted at some of the dams. Accurate information received from a patrolman may prevent the trouble entirely or else give the system operator time to plan for the most efficient way out of the trouble, should it prove to be inevitable.

System operators should give careful consideration to all high-tension line disturbances or surges that are reported. They may be caused by an arcing ground, and it is a well-established fact that trouble of this nature sets up surges and causes stresses, on delta-connected systems, which tend to weaken insulation on all lines and apparatus connected metallically to the defective part. Arcing grounds must be located and cleared from the system as soon as possible. An experienced operator should have little difficulty in locating transmission-line trouble on a modern high-tension system.

Weather conditions and approaching storms should be carefully noted and suitable preparations to take care of possible trouble should be made by checking up the whereabouts of patrolmen, linemen and repairmen. Reliable means of communication between the system operator and patrolmen, switching points and stations must be maintained, and the system operator should give this important matter careful thought and be prepared to act promptly should one of his lines of communication fail. System operators' messages over the private telephone line should be given preference, and it should be understood by all concerned that any instructions given by them regarding the generation and disposition of power should take precedence over all other instructions. Important messages should always be repeated.

The question of proper discipline is an important matter, and the morale of the men, as well as the condition of the equipment under their care, should have special consideration. All concerned should understand that co-operation with the system operator tends toward safe, continuous and efficient work.

STANDARDIZATION OF OVERHEAD CONSTRUCTION

Standardization of construction in any line of work results in decided advantages at any time, but especially so under present

conditions, says H. E. Wulfing of the Commonwealth Edison Company, Chicago. There are a few advantages peculiar to overhead line construction which will bear emphasis. First, standardization eliminates the carrying in stock of special material to satisfy the ideas of the several foremen or superintend-

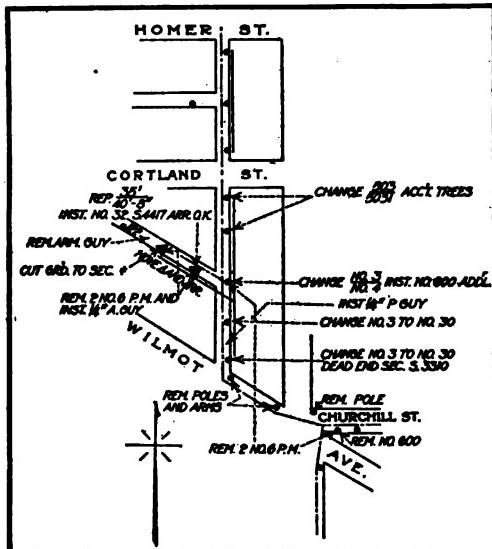


FIG. 43—TYPICAL METHOD OF INDICATING WORK ON JOB ORDER

ents engaged in the work. Next, it reduces the amount of material which has to be carried in stock by reducing the number of kinds of units needed. Third, it permits of accurately determining in advance the correct amount of material needed on each job, since the material for each standard is definitely known and the material for a job will be equal to the sum of the material for the standards in connection with the job. In addition, it increases the efficiency of the gang, owing to the fact that the repeated performance of a job in a definite way increases the speed with which it is done. Again, it establishes uniform construction throughout the system. Sixth, it permits a comparison of the relative value of the gangs, as each gang does the same units of work in the same manner. And last, but not least, it reduces the cost of doing the work.

The establishment of standards for overhead construction is

not so simple as in most other work, however. No two jobs are alike and, while the elements of a job may be similar, the conditions under which it will be done are different in each case. However, if overhead line work is to be made uniform, simple, neat in appearance and easy to designate, there must be standards. The method of establishing such standards for the Commonwealth Edison Company of Chicago are given in the following paragraphs.

In this program of standardization, which extended over a period of two years, several requirements were considered. They were safety, simplicity, neatness in appearance, uniformity, practicability, fitness for a progressive construction program, and cost.

How Cable Pole Construction Was Standardized. In order to give a concrete illustration of the manner in which some of these requirements have been met, the steps followed in standard-

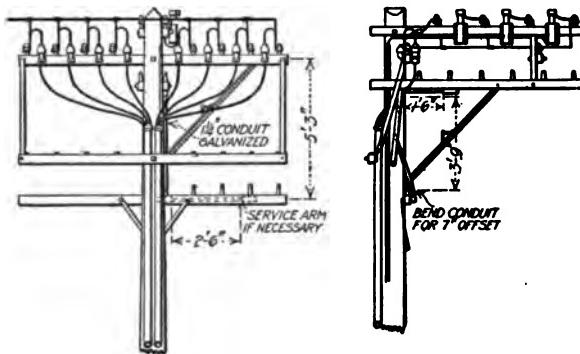


FIG. 44—STANDARD CABLE-POLE CONSTRUCTION ADOPTED

izing a cable pole will be explained. When the standardization of cable poles was considered it was found that there were several types of construction in existence. This condition existed because men in charge of work in various districts had followed their own ideas and worked independently. The best type was selected, and the question of safety was first considered. This pole contained six alley arms and three buck-arms and was designed to carry twelve potheads. It was found that the safety of the pole could be improved by adding another arm, on which the lineman could stand while inspecting lightning arresters.

This further loaded the already overburdened and unsightly pole. While the question of safety had thus been taken care of, simplicity of construction and neatness in appearance had been neglected. In order to attain this it was necessary to reduce the number of arms on the pole.

It was found that the number of cases in which it was necessary to install twelve potheads on a cable pole were few. Therefore it was decided to design the cable pole for eight potheads, taking care of the cases in which twelve potheads were needed by setting another cable pole. This permitted the reduction of the number of buck-arms by one. The standing arm, which was originally installed for safety in inspecting lightning arresters, was then eliminated by installing the non-inspecting type of lightning arresters. Further consideration resulted in the elimination of services from the cable pole, and a standard was finally adopted having only three buck-arms and four line-arms as against the old type, which had four buck-arms and seven line-arms. The new standard (Fig. 44) is safer, simpler, neater in appearance, more practicable and costs less than any construction which was formerly used.

A good illustration of progressive construction is given by the present type of standards for transformer installations. An in-

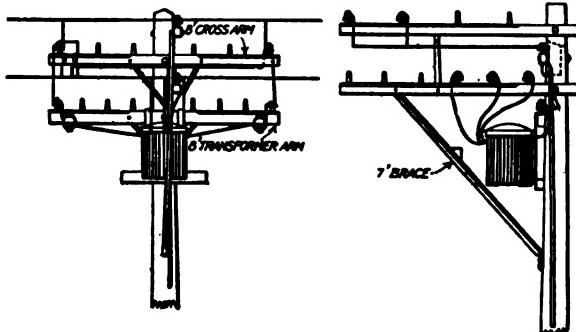


FIG. 45—TYPICAL CONSTRUCTION FOR SMALL TRANSFORMER INSTALLATIONS

vestigation of the different types of construction brought out the fact that, as was found with the cable poles, there were many methods of installing transformers. It was also found that as the load on a transformer increases, and it is necessary to increase its size and therefore increase the strength of the equipment for

holding the transformer, it would be practically necessary in most cases to dismantle the previous construction and rebuild the transformer pole. Safety and appearance were already fairly well taken into consideration, so that the main question was one of progressive construction.

In the plan which was finally adopted the transformers are divided into groups with a type of installation for each group. The installations are so planned that when it is necessary to increase the size of a transformer of one group to the next larger

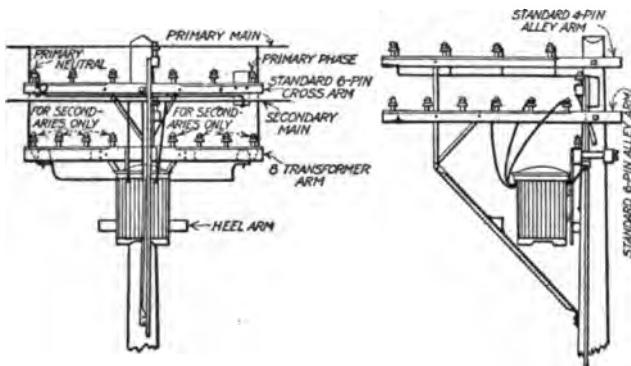


FIG. 46—AMPLE SPACE IS PROVIDED FOR LARGE TRANSFORMER BY BRACING USED, WHILE EXTRA STRENGTH IS AFFORDED BY DOUBLE BUCK-ARM HOLDING TRANSFORMER

it is merely necessary to add another arm without disturbing the existing equipment other than the transformer itself. Incidentally, simplicity and neatness in appearance were attained by providing heavier arms to support the transformers rather than by doubling the smaller sizes of arms (see Figs. 45 and 46). A change from the construction shown in Fig. 45 to that in Fig. 46 can be made by merely adding a short buck-arm for additional strength without any change in wiring.

Once having established a standard, there are two things to be accomplished in order to put this standard into effect: First, to familiarize the man on the job with the construction standard; second, to devise a scheme for specifying the standard on the job print. In order to keep the man on the job in touch with standard construction, each gang foreman is supplied with a book of standards known as the "Overhead Construction Specifications." This book is pocket-size and contains a description of

the methods of construction and prints of all the standards commonly used, together with a list of material for each type of construction. The foreman is thus furnished with authoritative information on whatever work he has in hand.

On account of the large number of standards of overhead construction, it was evident that some system of symbols must be

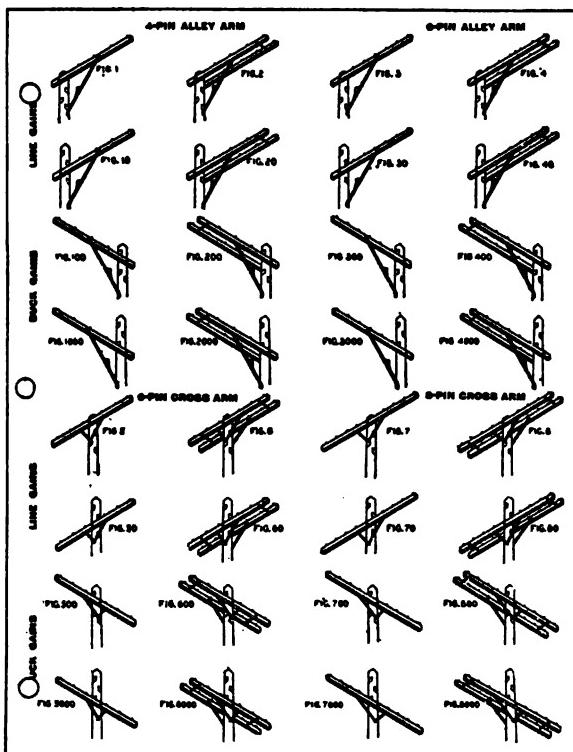


FIG. 47—POLE-TOP CONSTRUCTION CLASSIFIED BY POSITION OF CROSS-ARMS ON POLE

adopted in order that the standards might be classified and to permit ease of reference and specification on the job print. For this purpose the standards are divided into groups according to types—for example, cable poles in one group, transformer poles in another, line poles in another, etc. To each group is given a series of numbers sufficient to take care of the present standards

and to allow for future standards that may be established. These symbols or numbers for designating the different types of standard construction permit ready reference to the various groups and allow the use of simple specifications on the prints and job sheets. The foreman and men soon become familiar with the symbols and refer to the types of construction by symbol numbers instead of by description.

In attempting to establish standards for the overhead work, it was found that they naturally divide themselves into two groups —one line poles, the other special poles. The number of special poles is limited, and it was a simple matter to assign symbol numbers to them; but when it came to the question of assigning symbol numbers to line poles it was found that there were so many possible combinations of arms on a pole that the making of a sketch and assigning symbols to each combination was out of the question. It was therefore necessary to establish some scheme that would permit the definite designation of the arming of a line pole without the necessity of assigning to each group of arms a separate sketch and symbol.

Study on a scheme of this kind resulted in the application of a decimal system (Fig. 47) for designating the arming of line poles. For instance, referring to the group of small figures in this illustration, Fig. 1 is a four-pin alley arm on the top line gain. When placed on the second line gain it is called Fig. 10; on the first buck gain, Fig. 100, and on the second buck gain, Fig. 1000. The arm doubled is designated by the next even number. In other words, the number designates the arm, and the units, tens, hundreds or thousands in a figure designate the position of the arm on the pole. For example, Fig. 30 represents a six-pin alley arm on the second line gain—the figure 3 identifying it as a six-pin alley arm, and its being in the tenth position identifying its location on the second line gain.

The specifying of the arming of a line pole is thus reduced to a symbol consisting of no more than four digits, and any combination of four arms, either single or double, on any of the four positions can be specified by means of the decimal system shown. To illustrate further: Fig. 632 designates the arming of an ordinary line pole from which a service is taken and specifies that a double four-pin alley arm is installed on the top line gain, a

single six-pin alley arm on the second line gain and a double six-pin buck-arm on the first buck gain. The simplicity of the designating of the arming of line poles should be evident.

WOODEN TOWER FOR A LONG-SPAN CROSSING

To supply Camp Pike with service promptly the Little Rock Railway & Electric Company had to erect a 13,000-volt transmission line within a very short period. Since the camp was on the opposite side of the Arkansas River from the company's generating station, a 2000-ft. (606-m.) span had to be provided to cross the river. One bank of the river was about 160 ft. (48.7 m.) higher than the other, so that a relatively tall tower was required on the lower side. Not being able to secure steel towers on short notice, the company erected a wooden one.

The tower was constructed of four 75-ft. (23-m.) red-cedar poles securely embedded in concrete and cross-braced with 6-in. (15.2-cm.) diagonals. Cross-arms, 4 in. by 6 in. (10 cm. by 15.2 cm.), were used.

The total cost of the tower, which, furthermore, was completed in the required time, was less than one-tenth that of the steel tower of the same strength. Of course, the wooden structure will not have so long a life as a steel one would have had, but it is adequate for the purpose, as service will have to be supplied only temporarily.

BRACING LINE TOWER

By means of attaching a latticed structure to an ordinary straight-away line tower and then guying it at right angles to the line a company in New England was able to use a standard tower where an angle tower would ordinarily have been required. By so doing it avoided buying a special tower which would have been more expensive than the structure used.

A branch line is attached to the tower at right angles to the through line at this point. This arrangement has proved perfectly satisfactory from a structural point of view, and in these days when economy has become compulsory it has much to recommend it.

STEEL CONDUCTORS FOR SERIES CIRCUITS

Although the use of steel conductors in transmission and distribution circuits has advanced considerably, writes L. M. Klauber, superintendent Electric Department San Diego Consolidated Gas & Electric Company, as a result of recent material markets, many companies still hesitate to use the cheaper metal because early experiments in some cases proved failures. Such failures have been both mechanical and electrical. Mechanical failures have occurred owing to rapid corrosion of the conductor or to annealing following short circuits. Most of these cases, however, have been found upon investigation to have involved the use of solid conductors of comparatively small size, such as No. 6 or No. 8 B.W.G., attempts having been made to use conductors similar in mechanical form to the copper superseded. Extra-galvanized stranded steel, on the other hand, has long been extensively used for guys, and its life as a conductor may therefore be closely estimated by any central station, the estimate being based on the performance of guys in the same regions.

Electrical failures have been due to insufficient data on the electrical characteristics of steel conductors, and particularly to lack of consideration of the skin effect in solid conductors, which results in excessive drop at higher current densities. But extensive data on this subject have recently appeared, especially covering the stranded steel largely used in guys, so that the principal uncertainty which now remains has to do with the characteristics of the load, both present and prospective. Obviously, savings through the use of steel result primarily from the fact that in certain classes of lines copper of greater cross-section than is electrically necessary must be used for mechanical reasons. For this reason, an economical steel substitute will have less capacity for increased load than the copper replaced. It is therefore essential in designing steel lines that regulation and losses be closely calculated and that suitable allowances be made for future load increases.

One case in which most of the factors and results may be closely calculated in advance has to do with the use of steel conductors in series street-lighting circuits. In this case current and hours of use are fixed so that losses may be predetermined exactly. Since increased load involves increased pressure per

circuit or increase in number of circuits, there is not the possibility of having to replace steel with copper upon acquisition of unexpected new business. Furthermore, there is no possibility of deterioration of the line by annealing during short circuits. If stranded steel guy cable is used, the life may be gaged from previous performances.

Formula for Choice of Conductor Material. It is obvious that the economical choice between steel and copper will depend on a number of factors which are different for each individual case. Of fundamental importance are the costs of the two materials, rates of interest and depreciation and the cost of energy. In general, it may be said that steel will be the cheaper when the annual fixed charges on a copper line are greater than the fixed charges on the steel line plus the increased energy losses by reason of the use of steel plus the fixed charges on the additional constant-current substation apparatus required because of the greater losses in the steel as compared with copper. Stating this in the form of an equation:

$$F_c C_c - F_s C_s - L(HW + F_e C_e) = X.$$

It will be more economical to use steel when X is positive; when X is negative copper is preferable.

In the preceding equation, F_c , F_s and F_e represent respectively the rates of interest plus depreciation on copper lines, steel lines and substation equipment. C_c and C_s represent the first cost of unit lengths of copper and steel lines. This cost must be the cost in place, including overhead expense, since when lines must be removed the total cost in place must be retired from service. C_e represents the first cost of series lighting transformers per kilowatt. L equals the excess loss in kilowatts in a unit length of steel over copper. This quantity evidently depends on the current in the series circuit and the relative resistances of the two conductors at this particular current density, it being remembered that the alternating current resistance of the steel varies with the current density. H represents the annual hours burning in the street-lighting system under consideration. W is the cost of energy per kilowatt-hour delivered at the substation buses; this item should, however, include only those elements of production cost which vary with output (*i.e.*, fuel cost in steam plants).

Were the relative prices of steel and copper to remain in con-

stant ratio with markets fluctuating proportionately, either the one metal or the other would be invariably preferred for certain circuits. This, however, has not been the case, especially under recent abnormal conditions, as shown by Fig. 48, which gives the relative costs of steel and copper deduced from the purchasing department records of one central station for the last eight years. It may be seen that the cost of copper wire has varied from about twice to nearly five times the value of steel wire. Under such changing conditions it is logical that sometimes one and sometimes the other metal is more economical.

Application of Formula to a Particular Case. In order to illustrate the application of the above formula, two cases are assumed, one comparing bare copper with bare steel, the other double-braid weatherproof copper with weatherproof steel. The prices assumed should not be considered as indicative of present costs, since they are rather those which applied some months ago :

In giving values to F_c , F_s , and F_e interest is taken at 6 per cent. Bare copper is assumed to have a life of thirty years and a junk value of 40 per cent. (In each case the junk value represents the sale price as junk less cost of removal.) Weatherproof copper is presumed to have a twenty-year life and a 30 per cent junk value, since the serviceable life of an insulated conductor is in reality the life of the covering; for, regardless of the life of the metal, it must be removed when the covering becomes abraded. For



FIG. 48—FLUCTUATIONS IN RATIO BETWEEN COPPER AND STEEL COSTS DURING NINE YEARS

this service weatherproof steel may be assigned the same life as copper, although the junk value will be zero. Bare double-galvanized steel under normal conditions (away from salt fogs or corrosive fumes) is assumed to have a life of fifteen years and to be without net salvage value. Constant-current transformers are assigned a life of thirty years and a salvage value of 10 per cent. Basing depreciation calculations on the straight-line

method and adding interest at 6 per cent, the following conditions exist:

	Weatherproof	Bare
F_c	0.095	0.080
F_s	0.110	0.1267
F_o	0.090	0.090

Practically all series lines are No. 6 copper, so only this size will be considered. The best steel substitute appears to be $\frac{1}{4}$ -in. (0.63-cm.) extra-galvanized standard steel strand. Assuming copper (weatherproof or bare) at 34 cents per pound (75 cents per kilogram) at the storeroom, bare steel at 8 cents (17.6 cents) and weatherproof steel at 11 cents (24.2 cents), adding 4 cents per pound (8.8 cents per kilogram) as the cost¹ of stringing and 15 per cent overhead, and considering 1000 ft. (304.8 m.) as the unit of length throughout, with bare copper weighing 79.5 lb. per 1000 ft. (118 kg. per km.), double-braid weatherproof copper 100 lb. (149 kg. per km.), bare steel 125 lb. (185 kg. per km.) and weatherproof steel 155 lb. (230 kg. per km.), the following is true:

	Weatherproof	Bare
C_c	\$43.70	\$34.74
O_s	26.74	17.25

(O_e is assumed to be \$12.50.)

In the determination of L the resistance of copper is taken as 0.395 ohm. Within the comparatively small range of commercial alternating-current series circuits (4 amp. to $7\frac{1}{2}$ amp.) there is little change in the resistance of $\frac{1}{4}$ -in. (0.63-cm.) galvanized steel, the total increase at the higher density being about 3 per cent above the lower. This is less of a variation than that found between individual samples and may therefore be neglected. The 60-cycle alternating-current resistance of $\frac{1}{4}$ -in. (0.63-cm.) extra-galvanized seven-strand standard steel at these densities has been found by various investigators to be from 1.62 ohms to 1.78 ohms per 1000 ft. (5.3 ohms. to 5.8 ohms. per km.). Taking 1.70 as an average, and assuming a 6.6-amp. series circuit, $L = 0.0568$, H may be taken as 4000 for all-night lighting circuits, 2600 for moonlight and 2200 for midnight circuits. W

¹ There is practically no difference in the cost of erecting copper and steel.

obviously differs for each individual case and is here taken at \$0.005.

Substituting the preceding values in the equation, the following values of X are obtained:

Circuit	Weatherproof	Bare
All-night	0.01	— 0.61
Moonlight	0.41	— 0.21
Midnight	0.52	— 0.10

Thus in each assumed case it will be found more economical to use weatherproof steel rather than weatherproof copper, but bare copper (if line and ordinance conditions permit the use of uncovered conductors) is to be preferred to bare steel.

Assuming the same constants but a 4-amp. circuit, $L = 0.0209$; therefore it will pay to use steel in every instance.

Most Economical Size of Wire to Use. Of the various sizes of standard steel strand, $\frac{1}{4}$ -in. (0.63 cm.) will usually be found preferable for series circuits. Smaller sizes lack strength and are not so readily obtainable as the sizes used for guys. Although largely used in multiple circuits where steel is employed, $\frac{5}{16}$ -in. (7.9-mm.) cable will generally be less economical than $\frac{1}{4}$ in. in series circuits. This can be shown as follows: Consider $\frac{5}{16}$ -in. bare steel weighing 210 lb. per 1000 (312 kg. per km.) and double-braid weatherproof weighing 255 lb. (378 kg. per km.). By substituting the same unit prices and depreciation rates as were assumed in the case of $\frac{1}{4}$ -in. cable, omitting fixed charges on substation equipment, as they are of minor importance, and assuming that the alternating-current resistance of $\frac{5}{16}$ -in. (7.9-mm.) standard strand is 1.25 ohms per 1000 ft. (4.1 ohms per km.) at the current densities under consideration, the original equation reduces to:

$$1.486 - 0.45I^2HW = X \text{ for bare}$$

$$\text{and } 1.898 - 0.45I^2HW = X \text{ for weatherproof.}$$

Thus for 6.6-amp. series circuits it will be more economical to use $\frac{5}{16}$ -in. (7.9-mm.) strand than $\frac{1}{4}$ -in. (0.63-cm.) cable only when the cost of energy per kilowatt-hour at the substation exceeds the following:

	Weatherproof	Bare
All-night	\$0.024	\$0.019
Moonlight	0.037	0.029
Midnight	0.044	0.035

It may therefore be seen that $\frac{1}{4}$ -in. strand is to be preferred in all ordinary cases.

Other Considerations That Affect Choice. Of course, in a problem of this nature, involving a choice between copper and steel, or between two sizes of steel, the mere balancing of reduced fixed charges against increased operating expenses is not always the sole controlling factor. Where work is of a temporary character, as for camp or protective lighting, the element of depreciation which operates so strongly in favor of copper is more nearly

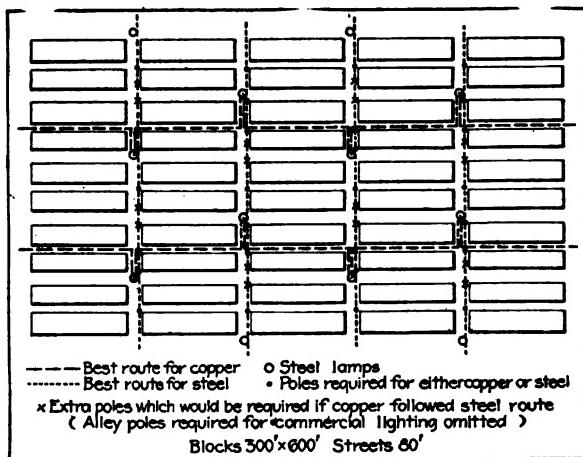


FIG. 49—COMPARATIVE LAYOUTS USING STEEL AND COPPER

equal for the two metals, and steel is usually to be preferred. Again, there are occasions when difficulty in raising funds renders desirable a reduced cost of installation, even at the expense of slightly increased operating expenses over a term of years.

There are other cases in which considerable savings may be made in first cost, owing to the increased tensile strength of the steel permitting wider pole spacings. An example of such a case is shown in Fig. 49. It is assumed that blocks are 300 ft. by 600 ft. (91 m. by 183 m.), with 80-ft. (24-m.) streets, and that commercial lighting feeders and mains are run in the alleys. The most economical system of covering the territory with steel takes only about 62 per cent as much line as the copper method shown. Besides, the construction is much simplified at corners and many

dead-ends and anchors are eliminated. The route outlined for the steel circuit is impossible with copper unless extra poles be added as indicated. This would considerably increase the cost and would be undesirable from a public-policy viewpoint, as it is preferable to have poles only on street corners where they carry street lamps.

On the other hand, with steel conductors it is perfectly feasible and safe to jump 380 ft. (116 m.) from alley to alley in the blocks where street lamps are missing, thus permitting the simplified system of passing back and forth on cross streets.

LONG SPANS PERMITTED BY STEEL WIRES A SAVING

Steel conductors not only effect a saving due to reduced cost per unit of length, but also, owing to greater tensile strength and reliability, permit wider spacings in supports. Poles, cross-

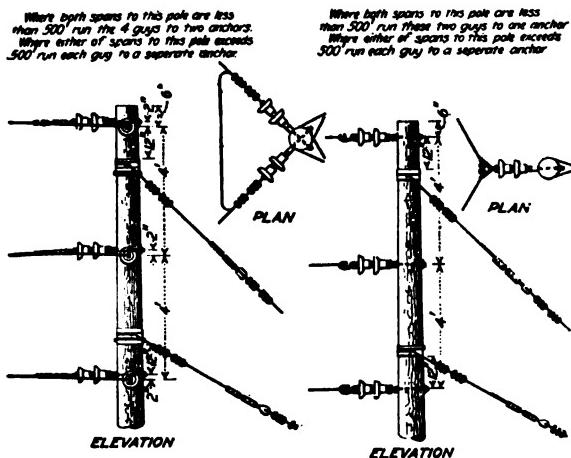


FIG. 50—CONSTRUCTION EMPLOYED FOR 70-DEG. TO 110-DEG. ANGLES AND FOR 0 TO 70-DEG. OR 110 TO 160-DEG. ANGLES

arms, insulators and line hardware have all advanced greatly in price and the reduction in the cost of supporting structures by the use of steel is as important as the saving in the conductor itself.

The Pacific Coast companies have for some time past used comparatively long pole spacings with copper conductors and wood-pole lines. Standard spans of 350 ft. (106.7 m.) with No. 6 or

No. 4 solid, or 450 ft. (137.2 m.) with No. 2 or No. 1 stranded medium hard-drawn bare-copper conductors, have been used extensively without the slightest difficulty.

With the advent of steel conductors it was seen at once that these spans could be greatly exceeded with absolute safety. After several branches were put in by the San Diego Consolidated Gas & Electric Company, using $\frac{1}{4}$ -in. (6.3-mm.) standard steel and 550-ft. (167.6-m.) spans, 700 ft. (213.4 m.) was selected as a standard, and many miles of line have been built with spans of this length. Naturally, large sags were necessary with these spans. Although flat construction had always been used in distribution circuits employing copper conductors, the old-style tri-

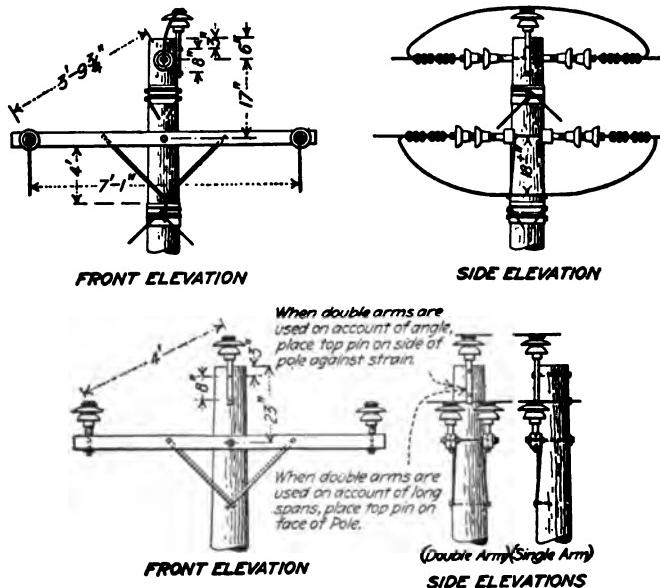


FIG. 51—CONSTRUCTION EMPLOYED IN SPANS NOT EXCEEDING 1000 FT., OR 175-DEG. TO 180-DEG. ANGLES (USE DOUBLE ARMS AT ALL ANGLES, CROSSINGS, AND FOR SPANS 500 FT. OR LONGER) AND FOR DEAD-END POINTS, OR 160-DEG. TO 175-DEG. ANGLES (IN TANGENTS OVER ONE MILE IN LENGTH USE ONE PER MILE)

angular construction, with a pole-top pin, was adopted, with steel to give greater clearances between conductors.

The use of steel conductors and long spans introduces no difficulties. With the greater strains experienced, guying at corners must receive careful consideration. As a rule stubs must

be specially heavy and anchored. Anchor guys must be used in quantity; at sharp corners four and six anchors to the pole are occasionally required.

The San Diego company had by the beginning of 1918 installed in main or branch lines exceeding a mile in length 68.6 circuit miles (201.3 wire miles) of steel conductors of $\frac{1}{4}$ -in., $\frac{5}{16}$ -in. $\frac{3}{8}$ -in. standard steel. In addition there are 25 miles (75 wire miles) under construction. Also there are 52.5 wire miles of $\frac{1}{4}$ -in. steel in constant-current series circuits. Most of the constant-potential circuits are 11 kv., although a few are 2300 volts.

A brief summary of the specifications used in a recent 11-mile (17.7-km.) extension of an 11 kv. line follows:

Conductor.— $\frac{3}{8}$ -in. extra-galvanized, standard steel, seven-strand.

Spans.—700 ft. Vary as dictated by topography of country, taking advantage of knolls and hill tops. Spans not to be shortened at corners. Maximum single-pole spans to be 1000 ft.; terminate spans exceeding 1000 ft. on double pole structures. In spans exceeding 1500 ft. use high-strength steel. Shorten spans to 200 ft. where possible in crossing railroads, main highways and telephone toll leads.

Clearances.—Minimum clearances over railroads, 28 ft.; over traveled highways, 24 ft.; over other supply lines or communication lines, 6 ft.

Poles.—Class A Western red cedar with open-tank treated butts. Standard pole on tangents, 40 ft.; at corners, 45 ft. Other lengths as required by topography. Set at N. E. L. A. standard depths. All poles to be shaved and gaining at pole yard.

Wire Arrangement.—Triangular with vertical corners.

Transpositions.—Six-mile barrels unless by special agreement with communication companies.

Cross-Arms.— $3\frac{1}{2}$ -in. by $4\frac{1}{2}$ -in. by 8-ft. Douglass fir, painted with two coats of yellow cement paint.

Braces.—28-in. galvanized N. E. L. A. standard.

Pins.—St. Louis Malleable Casting Company No. 435 R galvanized with felt insertion.

Pole-Top Pins.—Hubbard No. 3020.

Insulators.—Ohio Brass No. 12546 or Locke No. 5155 (27,000 volts).

Strain Insulators.—Locke No. 3039 in pairs. A complete dead-end consists of one spring clevis, two No. 3039 strain insulators, $\frac{3}{8}$ -in. galvanized thimble and two three-bolt guy clamps.

Tie Wire.—Galvanized steel. Use one strand of the $\frac{3}{8}$ -in. conductor 48 in. long. Use a double back tie.

Splices.—Splice with five three-bolt guy clamps and two $\frac{3}{8}$ -in. thimbles. No solder.

Guys.— $\frac{3}{8}$ -in. extra-galvanized standard steel, same as conductor. Use double sets of three-bolt guy clamps.

Guy Insulators.—White's No. 506. Use one strain insulator in each guy, 4 ft. to 8 ft. from the pole. Also in the lower ends of guys attached to stubs not anchored.

Anchors.—Use pyramidal concrete anchors except in marshy ground, where treated wood slugs must be used. Where spans adjacent to corners exceed 500 ft. use pairs of anchors. Anchor stub guys in soft ground or where stub holds a corner adjacent to a span exceeding 500 ft. Anchor rods to be standard $\frac{3}{4}$ -in. galvanized, 8 ft. long. Use anchor boxes where required for the protection of persons.

Stubs.—Stubs to be Western red cedar poles 16 ft. 9 in. to 19 ft. 6 in. in length. Minimum top, 28 in.; minimum circumference 6 ft. from butt, 34 in.

Switches.—Line switches, Pacific Electric No. 1420; transformer switches, Pacific Electric No. 422-F.

Hardware.—All bolts, clamps, lag screws and miscellaneous hardware to be galvanized in accordance with N. E. L. A. specifications.

Special Foundations.—Set poles in concrete at heavy marshes. Use trussed pole set in concrete or push brace where anchors cannot be placed.

DETERMINING LABOR COSTS

In order to find out if it will pay to supply a prospective consumer with electric energy it is always well, writes A. G. Drury, to determine beforehand the cost of material and labor. The labor cost has risen to such an extent recently that the old methods of estimating this cost have grown obsolete. A rule that can be applied at any time is one that uses the man-hour as a basis of cost—that is, the number of men multiplied by the hours they work. This figure may be multiplied by the prevailing wage.

From a study of the time required to perform various line construction operations the author has concluded that the following units are conservative for checking estimates: Loading and unloading one pole, 2 man-hours; haulage per mile, 15 man-hours; digging and setting one 35-ft. (10.6 m.) wood pole, 4 man-hours; equipping one four-pin cross-arm with pins and insulator and attaching to pole 2.5 man-hours; stringing and tying 100 ft. (30.4 m.) of conductor to insulators, 2 man-hours.

While the time required for the different items of construction

may seem liberal, consideration must be given to the fact that some time is lost both at starting and afterward.

SERVICE INSTALLATION BY ONE CREW

Handling all of the operations that go to make a customer's service installation complete in one job through the use of a single crew saves the St. Joseph (Mo.) Railway, Light & Power Company considerable money. Estimates made by the distribution department place this saving at \$2 per service.

The crew, consisting of one foreman, two linemen, one groundman and one meterman, is able to string No. 6 B. & S. gage service wire to the consumer's premises, install the meter and connect the line so that energy is available in about one-half hour. The average cost of labor, including a charge of 30 cents per hour for maintenance of the crew's automobile, amounts to \$1.11. The best record which such a crew ever made for installation of services in one day is sixty-five. Another advantage of this arrangement is the psychological effect upon the customer who sees the work completed by one set of men instead of by several crews with a long lapse of time between operations.

UTILIZATION OF SECOND-HAND LINE MATERIALS

Of course, economy must not be allowed to interfere with maintaining a high standard of service; but, in attempting to decrease expenses by the standardization of equipment and the adoption of more efficient or durable apparatus, sight should not be lost, states L. M. Klauber, Superintendent Electric Department, San Diego Consolidated Gas & Electric Company, of the economy of utilizing discarded material and equipment. Here is where the construction department, which acts in the capacity of contractor to the operating department, has an opportunity to determine how this so-called scrap material can be utilized to best advantage.

With the increased cost of all raw materials, a careful study of scrap, that is, material which can be disposed of only as junk, should be instituted by all central stations. Metals, alloys, scrap rubber, etc., should be carefully segregated as to quality, so that the highest price may be obtained for each. The degree of segre-

gation which should be practiced will depend upon the specific conditions in each case, the quantity of each class of scrap accumulated, and proximity to raw material markets. Disposal direct to junk dealers will save much trouble, but in any case a certain segregation is advisable. A miscellaneous scrap heap is the junk man's picnic; he pays a skim-milk price, based on the least valued metal in the pile, and then separates the cream in the privacy of the junk yard. Other material and equipment can be renovated and used for a new service which is not so exacting.

Methods of Utilizing Old Poles. Poles form the greatest bulk of distribution plant removed. Poles of adequate length and size can be retreated and used again, if not too badly deteriorated; others may be too light or too worn. It becomes necessary, therefore, to segregate returned poles into three general groups—those which may be reissued as poles for standard work, those too light or short for such work, and those no longer of any value as poles.

Retired poles which are deemed adequate to re-use as such by a power company must first be carefully examined for soundness. The butt can usually be sawed off about 6 in. (15.2 cm.) above the old ground line if weakened by decay. In fact, it usually pays to discard the butt if decay has advanced beyond a surface sap rot. Sometimes about 3 ft. (0.9 m.) of the butt can be removed so that when the pole is reset the deteriorated portion falls so far below the surface that it will not be subject to rot. In any case the pole should be carefully treated to arrest further decay, otherwise the life after reinstallation will be short. Brush treatment is better than nothing, but an open-tank treatment is much to be preferred.

In these days of greater strength of construction and wider clearances, the 30-ft. (9.1-m.) poles with 5-in. (12.7-cm.) tops, commonly referred to by linemen as "toothpicks," have little place. In a rapidly growing community they accumulate in considerable quantities. Installation on rural branch lines often solves the problem of their disposal. In some locations villa lots are so large that a special-service pole is required between the main lead and each house. An old 30-ft. or 25-ft. (9.1-m. or 7.6-m.) pole serves well for this purpose. Short poles can sometimes be used in rolling country on long-span work, where necessary clearances can be secured by taking advantage of the hill-

tops. A short pole as a push brace will often solve a difficult problem where anchor rights cannot be obtained. One avenue of disposal of light poles which must not be overlooked is to communication companies. Telephone and telegraph construction, especially in rural districts, is ordinarily of lighter quality than that of supply lines, and often a lot of light second-hand poles in sound condition can be disposed of to such companies at a price well above scrap value.

If a pole is no longer fit to use as such, the next best service to which it can be put is as a guy stub. Ordinarily a guy is a poor location for second-hand material, since failure is expensive and care must be taken not to employ stubs that are too light. If insufficient for use as stubs, poles may be cut up as anchor slugs or for crib-bracing unguyed poles under strain. Light pieces may be sold to farmers for fence posts. Poles are useful in all heavy construction work and can be disposed of to contractors, house movers and the like. Square redwood poles were once used considerably in some parts of the country before the price became prohibitive. They may be sawed up and put to a variety of uses, particularly in rough building work. They are also valuable in the construction of mudsills, bog shoes or crowfeet for holding poles in marshy ground, owing to the durability of redwood in the presence of moisture. A piece of redwood makes an especially good anchor slug.

Failing in all other uses, poles may be cut up for firewood. Yet they are not so well adapted to this use as might be thought. Cedar soon chars in the ordinary fireplace and burns with difficulty. It is a fact testified to by many operators that a pole which catches fire from a defective insulator will easily burn down at 2 A. M. in a heavy rainstorm, but will when cut and dry stubbornly refuse to burn up in a perfectly good fireplace.

Use of Discarded Cross-Arms. Non-standard cross-arms, even though in good condition, are difficult to place, since they will not match with new material and are especially bothersome when double-arm pairs are desired. Older cross-arms are liable to be small in every dimension—shorter, of smaller cross-section or with less clearance between pinholes. The clearance between the pins next to the pole is often less than permitted by law or good practice. A solution of the difficulty as to second-hand arms lies in their use as service buck-arms. Though more expen-

sive than brackets, the buck-arm has advantages as to clearances, making a neat and safe installation, especially where a number of services leave a pole in a variety of directions.

One company which utilizes retired non-standard arms for buck-arms places an average of 2000 arms per year in such service, thereby utilizing the entire non-standard accumulation. If these second-hand arms are found to have a "pole-pin" separation too narrow to comply with standard practice, it is a good plan to fill one of the pole-pin holes with a 1½-in. (4.31-cm.) wooden plug which can be nailed in place. A new through-bolt hole can then be drilled about 4 in. (10.16 cm.) off center toward the plugged hole and the arm mounted off center. This increases the clearance between the remaining pole pin and the pole by 4 in. Three pin positions remain available for use, these being all that are required for a lighting service. The offset buck-arm does not look bad on a pole, and, besides the advantage of increase clearance, it permits the use of one short or non-standard cross-arm brace with each arm, thus utilizing an additional second-hand item.

Other uses to which old cross-arms may be put are those which might be filled by any lumber of similar size, such as fence posts for wire fences, blocking for the storage of poles, cross-arms and other materials, cross-pieces for pole-hole covers, and, in general, rough construction work.

Reinstalling Old Wire. Weatherproof copper wire removed from the lines should be carefully examined before it is reinstalled. If the impregnating compounds have been fried out, it will be better to skim it at once and use it where bare wire is permissible rather than to have it become stringy and an eyesore in a short time. Many places will be found in suburban and agricultural districts where bare wire is as useful as weather-proof, provided that it has retained its strength. Some of the very oldest wire removed, particularly solid wire in sizes from No. 2 up, will be found to be crystallized and weakened by repeated bending. Such wires should not be reinstalled on the lines, as they will only result in failures. In reeling up second-hand wire for line use, the old splices should be carefully examined. Many will be found weak and of poor workmanship, since splicing was not so carefully done in the old days as now.

Short lengths of good quality, either weatherproof or bare, should be saved for ties. Annealed wire makes a better tie than medium hard-drawn, particularly when tying bare wire with bare wire. If wire is annealed and the insulation is removed by burning, the fire should be started in the open, not in any form of furnace, and the wire must not be allowed to become overheated or it will lose its strength.

One use to which larger sizes of copper can be put after the insulation has worn off, and even after the wire has crystallized, is for grounded neutrals in underground secondaries. Where secondaries are well grounded at transformers and where practically every service conduit is likewise grounded and tied to the neutral, insulated neutrals would appear an unnecessary expense. Such systems are in operation, using bare neutrals entirely from the transformers to the various branch terminals at customers' entrance fuses, and no difficulties have been experienced due to loading and heating of adjacent cable coverings by leakage currents.

Bare scraps may be used as ground wires on transformer poles, provided that the vertical run is covered with a wood molding or fiber conduit, as is usually done even where non-weatherproof wire is employed.

Places for Retired Insulators. Insulators, especially pin-type insulators, present a different problem. Unless entirely destroyed they are more liable to be unsuitable because of inadequacy than because of deterioration. Owing to developments made by the manufacturers, greater factors of safety can be required and are used than were deemed necessary some years ago, so that many of the insulators being retired may no longer be utilized for their designed voltage. Companies having lines of various voltages are sometimes enabled to use old insulators on lower-voltage systems. This seldom pays, however, if the voltage steps are large, so that cumbersome insulators, subject to breakage and unnecessarily large pins, must be provided for use at the lower pressure. Some companies serving extensive territories in which a variety of service conditions are encountered find that insulators which have become inadequate in one district may be utilized for lines of similar voltage in sections where conditions are less severe. For instance, companies with

lines along the seacoast may find that insulators which have proved to be inadequate under fog and spray conditions will give perfect service on the same lines in interior valleys.

Glass insulators, even of obsolete type, will ordinarily be found useful on secondary systems, provided that they have standard pin holes. Sizes smaller than those now standard for line construction should be used on service brackets.

On the whole, porcelain insulators, on account of their limited uses, offer a difficult problem when obsolete, and large numbers must be scrapped. It pays to have a few old types available for emergency connections and testing about any plant, for insulating stools and staging and for temporary service during construction work.

Strain insulators are more flexible devices, and if in good condition use may be found for most obsolete types. Glass "bobs," formerly used in large quantities in guys, are being abandoned for more dependable porcelain, but they will be found quite adequate for the house ends of service loops. They may also be used in the lighter types of guys, such as arm and bridle guys, and in dead-ending light secondaries. Two-bolt and small obsolete three-bolt guy chains should also be used up on these light guys.

Some prototypes of the modern clevis cap suspension insulator which are useful in dead-ending 11-kv. to 22-kv. lines are with difficulty made up into strings, as they have an eye at each end. These may be made up into neat pairs by using one new clevis cap unit at the line end of each pair, thus eliminating connecting links.

Uses for Old Pins, Space Bolts, Etc. The lead bushing is an exceedingly useful device in remodeling metal pins. Combination pins having a steel through bolt, porcelain base and wood thimble are becoming obsolete with most companies in high-voltage work, owing to the rapid digesting or destruction of the wood. The wood thimbles may be readily split off, and by means of plaster-of-paris molds these may be replaced by new lead thimbles, resulting in a pin actually superior in strength and durability to the original articles. Metal pins with obsolete threads may be bushed with lead and thus rendered serviceable where otherwise they must be scrapped.

All-wood pins are of little service when deteriorated, although

the shanks may be used as the pin-hole plugs for three-pin service buck-arms as previously mentioned.

One use of obsolete small cross-arm braces was mentioned in connection with these buck-arms. Other applications will be found in connection with special construction work, particularly around substations.

Light space bolts and through bolts, usually $\frac{1}{2}$ in. (1.27 cm.) where $\frac{5}{8}$ in. (1.59 cm.) are now standard, will of course be found of service in construction around any plant. There are also a few special uses to which these may be put in connection with line work. Where angle-iron braces are used with large-size cross-arms, two $\frac{1}{2}$ -in. (1.27 cm.) bolts are required with each brace, and these may be made up from old through bolts which have been shortened. The threaded end of a cut-off space bolt may be used as a stud with that type of pin which consists of a malleable-iron top and a separable stud bolt. Such studs with two nuts (one battered on) make good short bolts for attaching strain insulators to universal dead-ending clevises or similar devices. It is interesting to note that one of the few advantages which cut-thread have over rolled-thread bolts is in their use as second-hand material, the cut thread permitting modification for other uses better.

Pole steps are not installed by power companies these days to such an extent as formerly. At one time all poles were stepped. Now it is usually the custom to step only transformer, switch and arc-lamp poles and sometimes not even these. Consequently most companies accumulate a considerable stock of second-hand pole steps. On account of the hook shape they have many useful purposes in miscellaneous work. They can be employed as spikes for industrial railways, as tent stakes, as cable racks in manholes, and as form hooks and anchors for future extensions in concrete work. They are useful about a warehouse as hooks for tools and ropes. A few may be used inverted as hooks to hold the rink at the lower end of arc-lamp chains or ropes where reels are not used. Occasionally they may serve as lag screws. The communication companies are still faithful to pole steps, and they should not be overlooked as a possible outlet for the surplus.

Many forms of metal scrap are useful as reinforcing in concrete. If concrete anchor slugs are used, old bolts, pole steps and

braces will make excellent reinforcing. Short pieces of guy cable, whether new or retired, are also useful as reinforcing in any concrete building work. There is always a considerable waste in guying a line unless the men are careful in cutting to length and use short ends between the pole and the strain insulator. Where steel conductors are used short pieces of guy cable are unraveled for ties.

Brackets of old types can usually be disposed of in special service work. In these days of military camps wood brackets are useful for distribution systems among the tents. One company wiring a large camp used up a year's accumulation stringing secondaries bracketed on short square poles between tent groups and to latrines and messhouses.

Inclosed carbon arcs are giving way to gas-filled tungsten-filament units. The retired arcs may often be employed with slight modifications to house the incandescent lamps. Arc-lamps coils, whether series or shunt, are very useful around repair shops or laboratories and in the manufacture of home-made relays, switch mechanisms, etc. Therefore a number should be saved when lamps are scrapped. Arc-lamp carbons of obsolete size may be set up in groups and used as rheostats. A few old arc reels will be found serviceable around any plant as light hoists. Old shades, whether glass or steel, may be employed as reflectors with incandescent lamps. Clear-glass globes of the closed type can be sold to furniture stores for fish globes. Arc-lamp chains in long or short pieces will be found to serve many useful purposes. They are handy in threading through vertical runs of conduit. Short lengths will serve as pipe or conduit hangers under buildings. A secondary dead-end of the strain type, readily attachable to the end of any space or through-bolt and having all metal parts galvanized, may be cheaply made up with a porcelain strain insulator, a short piece of arc chain, a lap link and a dead-ending clevis.

Disposing of Other Materials. Transformers and meters when retired are generally returned to the manufacturers for credit on new goods. When this is not done some parts may be saved from the scrap pile to advantage. Transformer cases with leads intact make excellent waterproof cases for the installation of meters, instrument transformers or relays in the open. Occasionally a transformer case is needed in camouflaging a check

meter on the service of a suspected customer, and a small quantity of transformer laminations are always of use about a shop and should be saved out of the scrap heap. The same is true of coils with the insulation burned off, if the wire is not damaged, as a quantity of binding wire is needed about any shop or test room for connections, etc.

Linemen's gloves after breakdown on test are useful where acids or other corrosive substances are employed, as for instance in handling materials in the lye solution in gas-meter shops, packing plants, etc.

The disposition of short lengths of lead-covered cable is always a problem. These accumulate with startling rapidity, even when every effort is made to utilize the shortest length in stock on each new installation. When cable is scrapped it generally pays to strip the lead. When flattened out this is useful for packing, washers, pipe saddles, etc. When these are not needed the sheath can be melted into solder or pin thimbles.

Packing material should be conserved in the same manner as supplies. Sacks are useful in putting up orders for local line crews, and boxes, barrels and crates should be available for goods sent to district storerooms. Heavy lumber from large crates should be saved for pole-hole covers. Barrels are often necessary when holes are to be dug in sandy or marshy ground.

It is advisable to provide a special workbench for the renovation of discarded line material and to keep at least one store-room employee continuously at this work, so that he may become expert in decisions upon the utility and proper disposal of the various devices retired. In any case the foremen of the plant blacksmith, machine and carpenter shops, who ordinarily do not come into close contact with the line department, should be made familiar with overstock and obsolete materials, such as braces, bolts and lag screws. A knowledge on the part of these men of what is available will frequently save time and expense by permitting the substitution of second-hand line hardware for new stock in various routine repair and construction jobs.

GROUND PLATE PLACED UNDERNEATH LINE POLE

To eliminate the necessity of digging an additional pole for ground plates, the Binghamton (N. Y.) Light, Heat & Power

Company has adopted a standard method of placing the plate underneath the pole. When the pole line is constructed the hole is dug slightly deeper than necessary and a copper ground plate 22 in. (56 cm.) by 16 in. (40 cm.) is dropped into it. A copper wire wound spirally is soldered to the plate and connected to the neutral of the line. This method eliminates the digging of an additional hole at least 6 ft. (1.8 m.) deep and provides a permanent ground for the pole as well as the line. For about 8 ft. (2.4 m.) above the ground the wire is protected by a wooden molding, which helps to prevent the wire from being broken by teams or boys.

EASILY MADE CONCRETE GUY ANCHOR

There is shown in detail in Fig. 52 a concrete guy anchor used by the Winsted (Conn.) Gas Company which is proving

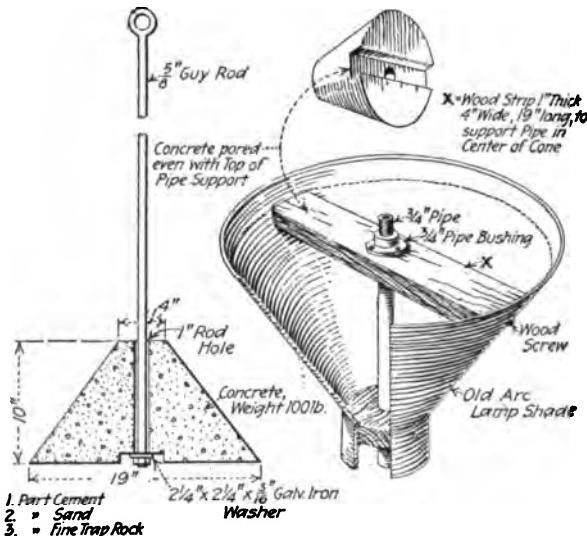


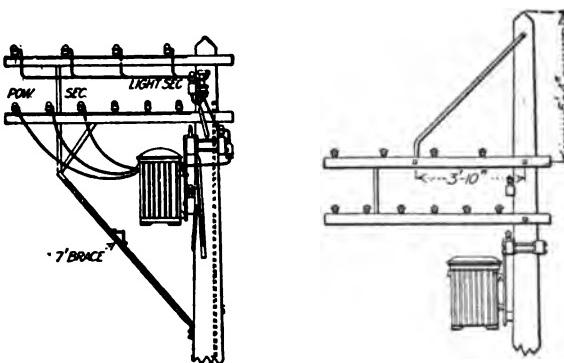
FIG. 52—DETAILS OF CONCRETE ANCHOR AND SHEET-IRON MOLD

satisfactory, states M. N. Longbothum. The anchor is made of concrete mixed in proportions of one part cement, two parts sand and three parts crushed stone that pass a $\frac{3}{4}$ -in. (19-mm.) mesh screen. The anchors weigh about 100 lb. (45.4 kg.) each. About three pails of concrete are used to fill the sheet-iron forms, which

were made from old arc-lamp hoods. The anchor is cone-shaped, 19 in. (48.3 cm.) over the base or largest diameter, with a 1-in (2.54-cm.) hole through the center for the insertion of a $\frac{5}{8}$ -in. or $\frac{3}{4}$ -in. (1.6 cm. or 1.9-cm.) guy rod.

MORE TRANSFORMER SPACE ON DISTRIBUTION POLE

As loads on distribution lines increase, transformers that were considered sufficiently large at first often turn out to be far short of present requirements. If transformers of larger size are required, it may happen that there is not room on the pole be-



Figs. 54 AND 55—PRESENT METHOD OF HANGING TRANSFORMERS AND PROPOSED METHOD OF BRACING CROSS-ARMS

tween the cross-arm and the brace. In order to eliminate this difficulty, a company in the Middle West is considering the advisability of changing its standard, which is shown in Fig. 54, to that shown in Fig. 55.

As may be observed, the proposed change consists of eliminating the arm brace under the cross-arms and installing a lighter brace above the arms. Of course, if the former clearance is to be maintained longer poles must be used, but it is thought by the company that the cost will not be increased because the pole top will not have to be as large as formerly. Besides, the size of the pole at the gains will be the same. Furthermore, the brace can be made from smaller stock because it will be intension instead of compression.

The result will probably be that the first cost will be lowered,

although this is not the main consideration. One feature is that it will be easier to hoist transformers on the poles on account of the increased height of the pole. Transformers as large as 100-kw. rating can be installed on these poles, whereas with the old construction the extreme maximum is 50 kw.

EXTENSION TO POLE TOP PROVIDES FOR EXTRA ARM

Having a pole already well filled with cross-arms and requiring six additional transmission conductors to parallel this line, an extra cross-arm was attached to the pole as shown in Fig. 56.

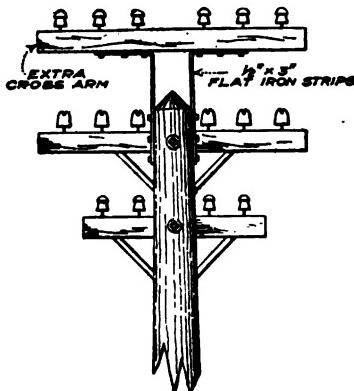


FIG. 56—EXTRA CROSS-ARM ON POLE-TOP EXTENSION

Flat iron strips 3 in. by 0.5 in. (7.6 cm. by 1.3 cm.) were attached to the pole near the top and bent at right angles at a suitable distance above the pole top. The extra cross-arm providing for six insulators was attached to these iron strips by means of lag screws. This scheme gave additional height to the pole and eliminated the necessity of another pole line. It has given satisfactory service, writes Frank Huskinson, on a transmission line one mile in length.

INEXPENSIVE OVERHEAD LINE CROSSING AT RAILROAD

Two three-phase transmission circuits of the Fort Smith (Ark.) Light & Traction Company have been strung across a railroad right-of-way on supports attached to an overhead bridge.

This type of construction was chosen in order to avoid the use of extra-high poles and to make a permanent job. The arrangement, as worked out, proved inexpensive.

At each end of the main bridge span tubular steel trolley poles were attached to upright members of the steel bridge by means of three large U-bolts. These steel poles were also braced at the top by guy wires and by an angle-iron framework which supported the trolley wire over the track. The fact that the high-tension circuits ran parallel to the track on one side of the railroad and at right angles to it on the other made different types of construction necessary at each support.

On one side strain insulators and short "pull-off" wires served to support the wires at this right-angle turn and to give ample clearance between the circuits and the steel bridge span. On the other side of the bridge seven strain insulators hung in a continuous string are supported between angle-iron mast arms attached to the trolley pole. The high-tension wires are then supported at the points between the strings of insulators.

THE OUTDOOR SUBSTATION

On account of the rapidity with which most of the materials covered by war contracts had to be delivered, industrial companies found that the building of isolated plants was out of the question, not only because of the time necessary for erection, but because of the low rates and excellent service furnished by utility companies. As a result central-station companies had to make numerous extensions to their plants to take care of the demands imposed upon them by the war industries. The difficulty of obtaining material on short-time delivery, the speed with which the installations had to be made, and the need of conserving funds, all made it imperative that all central-station equipment be utilized to the best advantage. With this idea in mind, many central-station companies adopted the practice of providing outdoor substations for serving the various war industries which were depending upon them for power.

The development of electrical apparatus and equipment has been such in recent years that it need no longer be operated indoors. The use of outdoor substations, therefore, according to E. B. Meyer, Assistant to Chief Engineer, Public Service Electric

Company of New Jersey, was one of the means of hastening the end of the war in that it was no longer necessary to provide costly fireproof structures for the housing of electrical equipment. Outdoor installations can be made at a greatly reduced cost and the saving in both labor and material is therefore an item which should not be overlooked.

For small outputs and comparatively low voltages the transformers are usually hung from a substantial pole directly underneath the transmission line itself, the switching equipment being mounted on cross-arms between the line and the transformer, and the transmission line carried on top of the pole. Transformers of larger output or higher voltages are mounted on platforms, sometimes they are arranged on steel towers and at other times on wooden structures supported between two or more poles, while the switching equipment is usually carried immediately above the transformer. For the largest outdoor substations the transformers are mounted on guarded concrete platforms, while all of the switching equipment and transmission lines are carried on steel towers of strong construction.

Substations of the portable type, with the apparatus mounted on wagons, floats or railway cars, are particularly adapted for breakdown auxiliary service, temporary peak loads, construction work or any of the other numerous war-time demands made upon the central-station companies.

It was originally supposed that the outdoor station created a greater hazard to the public than one in which all the equipment is housed, but this fear is groundless since with the property inclosed by a substantial fence the danger to the public is eliminated. With the outdoor substation there should always be less danger from fire, provided proper precautions are taken against the accumulation of inflammable material on the property.

Requirements of an Outdoor Station. In the design of an outdoor substation it is desirable that the installation be as neat and compact as possible. Usually elaborate switching equipment is not necessary to provide immunity from interruption as in most cases interruptions are so infrequent that the cost of providing duplicate and expensive equipment is not warranted. The outdoor installation, as well as all other forms of high-tension installations, should be so arranged as to make the operation as

simple as possible and at the same time provide ample protection to the operators and repair crews.

In a number of outdoor substations steel structures are used for mounting the buses, disconnecting switches and other equipment. The difficulty at this time of obtaining delivery on structural steel and the advisability of conserving this material for shipbuilding and other important war needs has made it necessary to look about for some other type of construction. Heavy wood poles and timber construction may be used to good advantage and at the same time reduce the cost considerably.

Storage of Oil During Transformer Repair. In installations where large capacity oil and water-cooled transformers are used it is sometimes necessary to provide a tank for storing the oil from transformers under repair. Oil tanks are usually built of boiler plate, but as this class of material is one of those on the list which must be conserved for war purposes, it is necessary to provide some other form of construction as a substitute. One large central-station company where a number of high-capacity oil and water-cooled transformers are used has experimented with a concrete tank for oil storage. In the particular installation in question a concrete tank 13 ft. by 6 ft. by 6 ft (4 m. by 1.8 m. by 1.8 m.) was built adjacent to the outdoor installations and so arranged that the oil can be drained from the transformers directly into the tank. The tank is built with a mixture of one part cement, two parts sand and four parts broken stone and reinforced rods to make a structure of sufficient strength to withstand the oil pressure. The interior of the tank is plastered with a waterproof compound, over which are applied several coatings of silicate of soda. An airtight cover is provided on the top of the tank and the necessary provisions are made to allow pumping the oil back into the transformers when repairs have been completed. It is not expected that the oil will have to remain in the concrete tank for any great length of time so that the leakage, if there is any, will be practically negligible. The matter of providing proper housing for repairs and storage of oil may at first seem to be somewhat of a refinement; it nevertheless is important in large installations if it is desired to keep the cost of repairs at a minimum and at the same time avoid delays in placing equipment back into service. In many instances lack of

attention to the matter of repair facilities has resulted in delays, with a consequent loss in revenue to the central-station company. It must not be inferred, however, that making repairs constitutes a serious difficulty, as with reliable apparatus and proper accessibility it is often easier to make repairs outdoors than indoors, where lack of room sometimes handicaps the repair men.

Cooling Transformers. Adequate cooling may be provided for transformers by three different methods: (1) Cooling tower; (2) spray pond; (3) deep-well pumping outfit. The objection to the spray pond is the amount of room required for this type of installation, as in order to obtain sufficient spraying surface an area 50 ft. by 50 ft. (15.2 m. by 15.2 m.) is required for even a moderate-sized installation. A cooling tower may be of two types, one commonly called the forced-draft cooling tower and the other the atmospheric cooling tower.

What might appear to be an objection to both the spray pond and cooling towers is the fact that in the hottest months when the greatest amount of cooling is needed the relative humidity is also greatest, consequently the theoretical dew point is raised so high that it becomes a rather difficult matter to bring the circulating water temperature down to the required value. In one installation, in order to overcome this difficulty a deep well was driven, and the water supply obtained from this well was practically constant all the year at a temperature of 52 deg. Fahr. (11.2 deg. C.). To dispose of the water a second deep well was driven and the circulating water pumped back into it and allowed to seep into the ground through the various earth strata.

The following figures were used in calculating temperature range for a cooling tower on the Atlantic seaboard:

Mean July temperature (deg. Fahr.)	73.0
Mean July wet bulb (deg. Fahr.)	67
Mean July humidity (per cent).....	71

Assuming water leaving the transformer coils at 100 deg. Fahr. (37.8 deg. C.), the temperature of water leaving the tower is obtained by substituting in the formula $T_1 = (T + 2t_1 + t) \div 4$.

t = temperature of atmosphere

t_1 = temperature of wet-bulb

T = temperature of water on tower

T_1 = temperature of water off tower

$$T_1 = (90 + 134 + 73.5) \div 4$$

$$T_1 = 74.4 \text{ deg. Fahr.}$$

During winter weather considerable trouble may be experienced due to freezing of the water in the pans, but by installing a by-pass valve and piping so as to utilize only the bottom tray the freezing is eliminated.

In conclusion it may be said that the modern up-to-date outdoor substation has come to stay and its evolution has gone steadily forward. The outdoor equipment is well adapted for furnishing both the small rural load and the more important industrial centers. It is far more simple than the indoor type and more space may be occupied with less money expenditure both in structures and equipment, with the resultant advantage that no needless expenditure has been made on useless inclosures and barriers.

The problem of cooling the equipment has been solved in both the small and large size installations so that it is no longer necessary to provide expensive housing for large capacity transformers.

High-tension insulators, terminals and switches have been developed to such an extent that they may be as safely operated outdoors as when installed under cover, free from the action of the elements.

The development of the outdoor substation has been one of the most important factors in the interconnection of high-tension electrical systems and by its means considerable fuel saving may be accomplished in that the most economical generating units may be employed for long-hour use for serving the transmission lines through outdoor substations feeding concentrated industrial centers.

In the days of conservation of labor and building material, the outdoor substation was a step in the right direction as its construction not only released the experienced labor employed in building construction but also released cars and barges which were used to better advantage in the transporting of coal and other materials which were of vital importance in hastening the victory of the Allies.

OUTDOOR SUBSTATIONS SIMPLE AND ECONOMICAL

The outdoor substation, according to R. E. Cunningham, Superintendent of Distribution, Southern California Edison Company, has proved to be the simplest and most economical means of serving large consumers, and the favorable climate of southern California makes its operation entirely reliable.

Manufacturers have produced outdoor-type transformers which are entirely satisfactory for all moderate voltages. It has therefore only been left to the operating engineer to select switching and protective apparatus and properly arrange the equipment. Most distribution outdoor substations have been equipped with fused-type switches. The experience of this company with such switches has shown that they are not entirely reliable on account of the inherent weaknesses of high-potential fuses. Particularly on three-phase service is trouble had with one fuse failing, allowing the motors to operate single-phase and in many cases resulting in burn-out of the consumer's equipment.

In order to overcome this condition, a local manufacturer has made for the company an automatic outdoor pole-top switch for service on 10,000 volts. The company has more than 200 of these switches now in use, all of them having given satisfactory service. This is a single-tank switch, equipped with three series overload trip coils, so that an overload on any wire of a three-phase circuit will entirely disconnect the service. The switch is controlled by pull cables from the ground, and the consumer can immediately restore the service in case the switch has been kicked out by momentary overload. This saves the consumer a long interruption which would otherwise exist, with the use of fuse switches, since the company would have to send out a troubleman to replace the burned-out fuses.

When extra heavy loads are to be started or fluctuating conditions are encountered, a simple time-limit device can be attached to the plunger of each overload relay, which prevents the switch kicking out except in cases of actual trouble or continued overloads. This switch also allows the consumer to disconnect his transformers when they are not in actual use, saving to the power company the energy lost in exciting the transformers and removing all hazard of energized wires on the consumer's property. With a switch of this type on the primary side of

the transformers installed within 30 ft. (9 m.) of the entrance to the property, the local authorities have ruled that the main entrance switch on the secondaries is not required.

MODERATE OUTDOOR SUBSTATION

The San Joaquin Light & Power Corporation of Fresno, Cal., has an outdoor substation near Madera, in the same State, which may be of interest because of its construction and moderate cost, writes L. J. Moore, Engineer San Joaquin Light & Power Corporation. Suspension construction on wooden poles is employed throughout. The San Joaquin corporation has always been partial to wood poles, owing to its proximity to the Oregon and Washington supply of timber. A quite extensive open-tank creosoting plant is maintained in Fresno for the treatment of poles which are used on the system. The present high cost of steel was also a factor in determining the use of poles for this substation. Other substations which have been erected by this corporation have usually been constructed with pin-type insulators on wood poles. All future installations are to be made with suspension insulators, thus making it possible to increase the amount of insulation installed and to secure better mechanical construction than is possible on pin-type insulators. Except for the metering equipment and low-tension oil switches all the equipment in the Madera substation was placed out of doors.

The substation is connected to a 66,000-volt line which forms a loop through a number of other substations. The transformation ratio is from 66,000 volts to 11,000 volts through a Y-Y bank of transformers with both high-tension and low-tension neutrals grounded. An oil switch and an air-break switch are installed in the incoming and outgoing 66,000-volt lines where they connect with the 66,000-volt bus which loops around the substation site. A spacing of 7 ft. (2.1 m.) has been used between high-voltage wires where possible to lessen the occurrence of arcs or trouble caused by large birds flying between the wires. The transformer bank is connected with the 66,000-volt bus through an air-break switch and an oil switch. Provision is made for seven 11,000-volt feeders, two of which are carried on the transmission-line poles. All 66,000-volt air-break switches used in the station are five-disk K-P-F switches, chosen because their construc-

tion especially fits them for use in this type of substation. A grounding switch is installed on each end of the 66,000-volt lines in order to ground either section of the line in case men have to work upon the line between this station and either one of the two stations adjacent to it. The two grounding switches are mounted

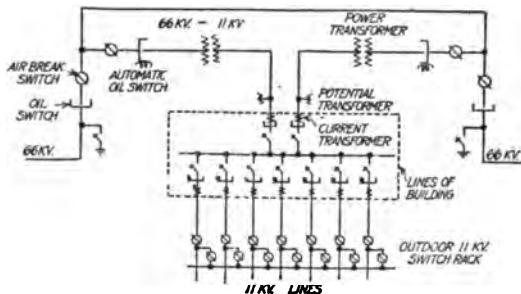


FIG. 57—ELECTRICAL WIRING LAYOUT OF MODERN OUTDOOR SUBSTATION SHOWING CONNECTIONS

on 66,000-volt pin-type insulators, which are the only high-tension pin-insulators in the installation.

The transformer bus is supported on 25-ft. (7.6-m.) poles and is long enough to accommodate two banks of three 500-kva. transformers, together with one spare and the controlling switches for both of the transformer banks. The 66,000-volt buses are on the arms across the tops of the poles, and the 11,000-volt buses are supported in a vertical plane on the poles themselves along one side of the structure. The buses are dead-ended in the center of the structure over the spare transformer so that it may be connected in place of any transformer in either bank which might become disabled. This location was chosen for the spare unit in order to minimize delay and work in connecting it into service.

In the center of the outdoor substation site is a corrugated iron-covered wood-frame building which houses the metering equipment and the 11,000-volt oil switches. All the equipment in the building could and would have been purchased for outdoor installation had it not been for the fact that this type of building adds no more expense than the difference in cost of outdoor and indoor type switches and metering equipment. Also, it was thought desirable to provide a building so that the operator would be near the indicating instruments and the automatic feeder

switches. If no building were provided, he would in all probability spend most of his time in his home, especially in bad weather, when line trouble would be most likely to occur.

The electrical equipment in the building consists of an 11,000-volt bus to which leads from the 11,000-volt side of the station transformers connect through a 300-amp., 15,000-volt General Electric K-12 oil switch and disconnecting switches. Similar equipment is installed on each of the seven feeders which tap off from the 11,000-volt bus. The switches and buses are mounted on pipe framework throughout. The feeder switches are auto-

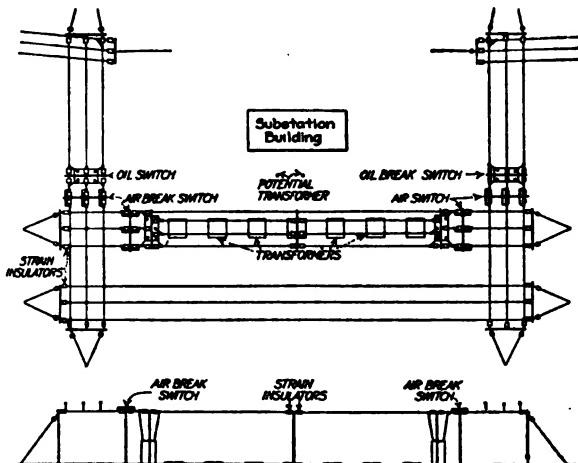


FIG. 58—ARRANGEMENT OF OUTDOOR SUBSTATION EQUIPMENT AT MADEIRA, CAL.

matic, but the switch on the transformer leads is not automatic. The metering equipment installed consists of three single-phase watt-hour meters, three ammeters, one Bristol recording voltmeter with a seven-day chart, and an indicating volt-meter which may be connected through a potential receptacle to any one of the three phases. This equipment is connected to current and potential transformers on the 11,000-volt transformer leads and measures the output of the transformers to the station bus. No metering equipment is installed on the individual feeders. Current transformers, however, are provided in each feeder for tripping the K-12 switches on overload or short circuit. Potential transformers for the metering equipment are installed on a pole

outside the building, the secondary leads being brought into the building through conduit. This potential bank consists of three 1-kw., 6600-volt pole-line transformers which are connected in star for 11,000 volts with the neutral grounded. An 11,000-volt, 2½-kw. pole-line transformer is installed in the same manner to supply lights for the station building and grounds.

A very convenient 11,000-volt switch rack and paralleling bus has been provided outside the building, and all 11,000-volt feeders pass through this rack to the out-going lines. A No. 1417 Pacific Electric & Manufacturing Company air-break switch has been installed on each outgoing feeder as a line "disconnect" to permit work on the oil switch inside the building. Each feeder taps outside this air-break switch through a second air-break switch to the paralleling bus, thus making it possible to attach any number of feeders to a single oil switch inside the building while repairs or adjustments are being made on the switches which are ordinarily connected with them. The long California summer causes all equipment to become very dusty if it is not cleaned often, so arrangements for taking apparatus out of service without interruption to it are very necessary in order to keep the equipment clean enough to operate satisfactorily and without danger of insulator flash-over due to the heavy coating of dust.

The substation site covers two acres, thus giving ample room for the necessary electrical equipment and the cottage for the operator. Only one operator is employed, because very little switching is necessary, and all of the automatic switches are provided with alarms so that in case one of them trips the operator is made aware of it. A 7-ft. (2.1 m.) woven-wire fence incloses the entire property, and a similar fence is installed around each of the 66,000-volt oil switches and any other equipment which might cause injury to any one coming in contact with it. The posts in the fence and the poles in the yard are painted a dark green. All cross-arms are painted yellow in accordance with a California state law.

The substation is provided with a private telephone connected with the corporation's private line, which is carried on the transmission line poles. Means for opening the telephone line and testing for trouble on it are provided. Connection to the ope-

rator's cottage is made both from the private line and from the Bell system.

At the time of writing this article the details of the cost had not been compiled in full, but as far as it is possible to determine from the data on hand the cost of the substation complete, including operator's cottage, well, fences and all details, was estimated to be in the neighborhood of \$15 per kilowatt of ultimate capacity.

INCREASING TRANSFORMER CAPACITY BY CIRCULATING OIL

When the main substation at Lincoln Park, Chicago, was built all multiple-circuit power was supplied by a bank of three 150-kva., 12,000/2300 volt, 60-cycle, single-phase, oil-filled, self-cooled, station-type transformers connected delta on the primary side and star on the secondary. These units were installed in an angle of the bus chamber as shown in the accompanying sketch. One spare transformer was provided but never used. Later a 200-kva., 12,000/2300-4000-volt, three-phase, oil-filled, self-cooled, station-type transformer was installed in the location shown and connected by means of double-throw disconnecting switches so it could be used in place of the 450-kva. bank. When this reserve equipment was put into service it was found that owing to the temperature of the bus chamber, which contains more than forty transformers, all of which are operated at night, the three-phase equipment became so hot as to be unsafe. The oil often attained a temperature of 75 deg. C.

To remedy this condition, writes Claude H. Sheperd, Electrical Engineer for the Lincoln Park Commissioners, a ventilating system was installed and operated in such a way as to change the air about once in five minutes. This helped but did not eliminate the excessive heating of the transformers, and it was feared that the interior layers of insulation were beginning to carbonize. Sludge was rapidly forming in the oil so it was feared that unless drastic steps were taken immediately some of the three-phase equipment might be lost as the heat was actually unbearable in the immediate vicinity of either the three-phase bank or the single-phase transformer, the room temperature often attaining 140 deg. Fahr. (60 deg. C.).

Consequently oil-cooling apparatus was purchased and installed, practically no interruption of service being experienced, although the work was done under the most adverse conditions and in close proximity to both the 4000-volt and 12,000-volt buses.

By reference to the drawing it will be seen that the transformer oil is drawn by a direct-connected centrifugal pump directly from the transformer cases into an accumulator or settling tank and thence into the pump, which discharges full volume into and through the cooling coils, the latter being immersed in constantly circulating water. From there the oil is discharged through a submerged outlet into the transformer. Two different suction systems were used. For the three-phase transformer

TABLE I—HEAT TEST ON 200-KW. TRANSFORMER MADE SEPT. 11, 1917

Time, A.M.	Temperature of Transformer,			Cooling-Water Temperature,	
	Deg. C	Kw.	Pump On	Pump Off	Deg. Fahr.
8:00	23	140	.....	8:00 a.m.	48
8:30	28	150	.....	.....	48
9:00	26	150	.....	.....	48
9:30	26	160	.....	.....	48
10:00	26	175	.....	.....	48
10:10	36	175	10:10 a.m.	.....	48
10:20	37	175	.....	.....	48
10:30	37	175	.....	.....	48
10:40	37	175	.....	.....	48
10:50	36	175	.....	.....	48
11:00	35	175	.....	.....	48
11:10	35	175	.....	.....	48
11:20	35	175	.....	.....	48
11:30	34	175	.....	.....	48
11:40	34	175	.....	.....	48
11:50	34	175	.....	.....	48
12 m.	33	170	.....	12:00 m.	48

the oil suction was taken through an already established connection at the bottom of the case, thus allowing automatic priming of the pump. In the case, however, of the three 150-kva., single-phase units it was found advisable to take the oil from the hottest part of the case, which was at the top next to the wall, the individual suctions being brought forward through the thermometer wells to regulator valves discharging into the main suc-

tion pipe or line. The discharge in each case was submerged and additional safety was assured by the use of fiber discharge nozzles.

It will be noted from Fig. 59 that section valves are placed in the two main suction lines and that individual regulator valves have been placed in each individual suction and discharge line, and that a pump throttle was also installed, giving absolute con-

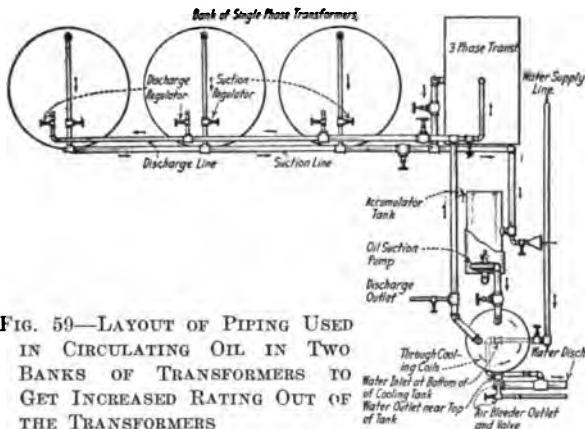


FIG. 59—LAYOUT OF PIPING USED IN CIRCULATING OIL IN TWO BANKS OF TRANSFORMERS TO GET INCREASED RATING OUT OF THE TRANSFORMERS

trol of the oil flow and allowing perfect adjustment under all conditions. A separate make-up funnel and valve were connected to the accumulator tank, and a T-connection and valve were placed in the discharge line, allowing oil to be either added to or taken away from the system at any time. With this arrangement it is obvious that the four transformer cases with oil at the proper level act as a reservoir system for each other, allowing levels to be adjusted or oil to be completely shifted from one case to another at any time. This plan gives assurance of great flexibility.

A thermometer is installed in the individual suction for each transformer and at the suction and discharge of the cooling coils, giving complete data on the temperatures. An oil gage is installed on each transformer to show the oil level and an air-bleeder valve is installed on the accumulator tank. The cooling water is supplied by the city system and is piped into the bottom of the coil tank. The overflow is installed near the top of the tank at such a level as to keep the coils always submerged. The

supply connection is made through a T at the bottom of the tank, the continuation of the supply line being connected through a stopcock into the overflow line. Hence by closing the supply

TABLE II—COST OF OIL-COOLING INSTALLATION

LABOR	
Machinist, 79 hours at 55 cents	\$43.45
Steamfitter, 92 hours at 48 cents.....	44.16
Helper, 79 hours at 38 and 40 cents	30.50
Class A electrician, 99 hours at 75 cents.....	74.25
	—————
Engineering and overhead	\$192.36 99.70
MATERIAL	
Fittings	\$8.59
One 14-in. by 30-in. galvanized-iron expansion tank.....	9.38
One 18-in. by 45-in. galvanized-iron tank with cooling coils	71.50
162 ft. 2-in. black pipe at 39 cents.....	6.42
Six 0-110 deg. C. thermometers	57.38
One 1/2-in. by 6-in. water glass .....	.10
Miscellaneous screws, bolts, etc.	9.31
Electrical conduit fittings	17.91
Piping and fittings for water supply	55.79
Transil oil .....	.80
24-ft. No. 8 fine stranded wire .....	.10
One oil pump driven by 1700-r.p.m., three-phase, 3-hp., 220-volt, 60-cycle motor, 50 g.p.m., 30-ft. head.....	165.00
Four transformer oil gages	6.28
	—————
Grand total	408.55 \$700.61

valve and opening the stopcock the tank may be quickly drained, a special air-bleeder line being provided to facilitate this operation. Three-phase energy is supplied to the pump motor from 220-volt taps on the secondary side of the main transformers. As the system is self-priming, no attention is paid to the pump during a shutdown as it will automatically come into operation again when the power supply is re-established.

For about six weeks during last summer the 200-kva., three-phase transformer carried in actual operation a maximum day load of 325 kw. for about five hours per day with a maximum oil temperature of 41 deg. C. (105.8 deg. Fahr.), and a cooling water temperature of 44 deg. Fahr. (6.7 deg. C.). The cooling system, it is apparent, has increased the capacity of the 200-kva. transformer over 60 per cent. As this has been the maximum multiple circuit load so far, the 200-kva. transformer should have ample

capacity when operated with the cooling system to "pull" the entire multiple-circuit load. In fact, since the installation of the cooling system it has never been necessary to operate the 450-kva. bank. Assuming the same relative percentage of core losses on both the 450-kva. bank and the 200-kva. transformers and allowing for the 1 kw. necessary to operate the cooling system, it is estimated that a net energy saving of \$0.72 per day is obtained with the cooling system in operation, energy costing 0.0075 cent per kilowatt-hour. Assuming a percentage increase in the capacity of the 450-kva. bank on the basis of 60 per cent, it will be possible to pull a load of 720 kw. on this bank. The only doubtful point is whether or not the interior layers of insulation are beginning to carbonize. This question will be investigated during the winter, but judging from the quality of oil now in the transformers no damage from this cause has appeared so far.

The test data in Table I show that in spite of the fact that the load was increased when the pump was started and remained at 175 kw. all night, the temperature of the circulating oil was steadily reduced from 37 deg. C. to 34 deg. C.

It will be noted that the temperature jumped from 26 deg. C. to 36 deg. C. when the pump was started, but this is due to the thermometer being in the suction riser. It indicates the riser temperature until the pump is started, thereafter the case temperature.

One change is necessary before the efficiency of the cooling system will be considered entirely satisfactory, and that is to substitute copper coils for iron pipe. The latter was used in place of copper because of the high initial cost of the copper. However, it has been found that for each passage of the oil through the cooler the temperature drop is from 2 deg. C. to 5 deg. C., whereas with copper coils it is expected that the temperature drop will be much greater. It is estimated that the investment in the present oil-cooling equipment earns about 37.3 per cent annually.

REMOTE CONTROL OF SUBSTATIONS SAVES MANPOWER

W. T. Snyder, electrical engineer for the National Tube Company, McKeesport, Pa., pointed to a year of successful operation

of a remote-controlled substation, at the annual convention of the Association of Iron and Steel Electrical Engineers, in a paper entitled "Remote-Controlled Substations."

Mr. Snyder made the statement that push-button control of oil switches and motor-operated rheostats permit the generating plant attendant to control the motor-generator sets in the substation which is locked up and unattended except for the daily inspection. Ammeters and voltmeters at the generating plant give the operator there all the information necessary for starting and loading the substation. Mr. Snyder states that the remote-control feature added about 10 per cent to the cost of the substation. This increase in fixed charges should be readily wiped out by saving in operating expense, in addition to conserving labor for other purposes. A great saving in copper was effected in the direct-current system by locating the substation near the load center.

ARRANGEMENT THAT SERVES PURPOSE OF DOUBLE BUS

In building the Antioch substation of the Great Western Power Company it was decided that the cost of a double busbar system

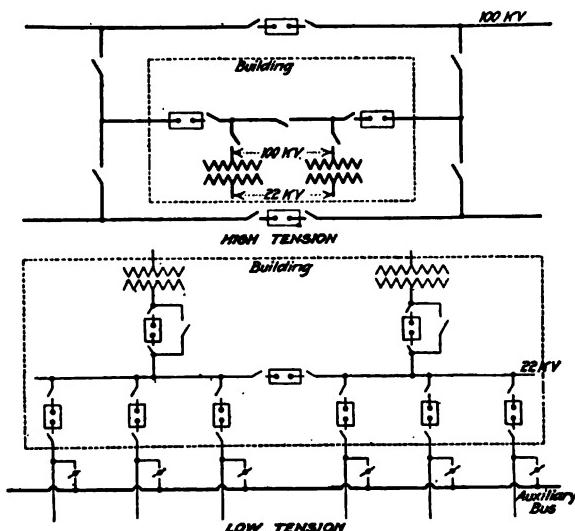


FIG. 60—**SINGLE-BUS SYSTEM IN SUBSTATION THAT ANSWERS THE PURPOSE OF DOUBLE-BUS ARRANGEMENT**

was not warranted solely by the flexibility it would afford. As an alternative plan a single-bus system was installed embodying an arrangement of cut-out switches that would permit obtaining about the same results as when a double-bus system was used.

The accompanying diagram (Fig. 60) shows the principle used, which provides for the isolation of practically every piece of apparatus in the station without interrupting the service. It is estimated that a saving of about \$8,000 resulted from the use of the arrangement which is here described.

SECTION III

THE SHOP

SHOP VERSUS FIELD TESTING OF NEW WATT-HOUR METERS

MANY central stations, according to George W. Hewitt, meter foreman of the Minneapolis General Electric Company, are actually wasting time and money testing new meters just received from the factory. Virtually all factories ship meters which are guaranteed to be accurate within 2 per cent. Testing the meters in the shop, carting them around all day in a vehicle, often installing them wrongly and not testing again for a year or so induces much "lost motion." "A shop test as compared with a service test, especially on direct-current meters, is not worth the money expended on it," says Mr. Hewitt.

In his opinion, the only test worth consideration is that made under actual service conditions. When the commutator of a direct-current meter, for instance, is polished and the meter adjusted it will be found that aging due to the oxidation of the silver commutator affects the meter and that a test made from thirty to sixty days after installation will show different results from a shop test or that made at the date of installation. Then, again, local and earth magnetic fields affect meters to a large extent, depending on the position of the meter. Errors of 5 to 10 per cent sometimes result from this cause.

The Minneapolis General Electric Company meter department does 90 per cent of its testing in service, holding its shop testing to a minimum. Meters which are repaired in the shop are adjusted within 2 per cent of complete accuracy, and new meters are not tested at all. They are thoroughly inspected and then tested within thirty days after the installation and adjusted to within 0.5 per cent of accuracy. The fact that 95.7 per cent of the installations tested are within the legal limit of 2.5 per cent accuracy seems to bear out the contention that this method of testing is satisfactory. According to the records, only eighteen

meters out of 4309 recently installed failed to register. This plan of testing meters after installation has the further advantage of being a check on the men who install the meters.

ECONOMICAL PRACTICES WITH METER JEWELS

Realizing that diamond meter jewels must be kept in service to justify their high first cost, the Minneapolis General Electric Company places these jewels in each instrument when the installation test is made but replaces them with sapphire when the service is disconnected. Thus money invested in expensive jewels is not allowed to become idle when meters are placed in stock. The diamond jewels are considered more economical when they can be kept in service because they will withstand 40,000,000 revolutions without showing appreciable wear, whereas sapphire will withstand only 700,000 revolutions before wearing out.

The extent to which the jewels are lubricated has also been found to affect their wearing qualities and the friction considerably. According to a test with jewels operating under three conditions—flooded with oil, with only a trace of oil, and dry—the jewel flooded with oil gives the best results and the dry jewel gives the worst.

CUTTING METER TEST LABOR

The best average record which meter testers of the Crawfordsville (Ind.) Electric Light & Power Company could make formerly, using the ordinary type of testing apparatus, was thirty-five single-phase meters per day. After rearranging all of the apparatus into a single compact unit the meter tester was able to average sixty meters a day for a period of ten days. The single-unit set, which is shown in Fig. 61, included the load box and calibrator and all of the connections. F. H. Miller, manager of the Crawfordsville company, said that considerable time is saved by the use of this set because connections do not have to be changed frequently, only about one minute being required to prepare the outfit for testing.

Details concerning the construction of the set follow: The outfit complete weighs 30 lb. (13.6 kg.) and measures 15 in. (38.10 cm.) long by 7.5 in. (19.05 cm.) wide by 10.5 in. (26.67 cm.)

high. It consists of a phantom-load box of the type made by the Eastern Specialty Company under the Herman & Mills patent, a Fort Wayne type M2 calibrator and the necessary connections and switches. The load box has a range of 0.25 amp. to 50 amp. of non-inductive load. The calibrator has a range of 1 amp.

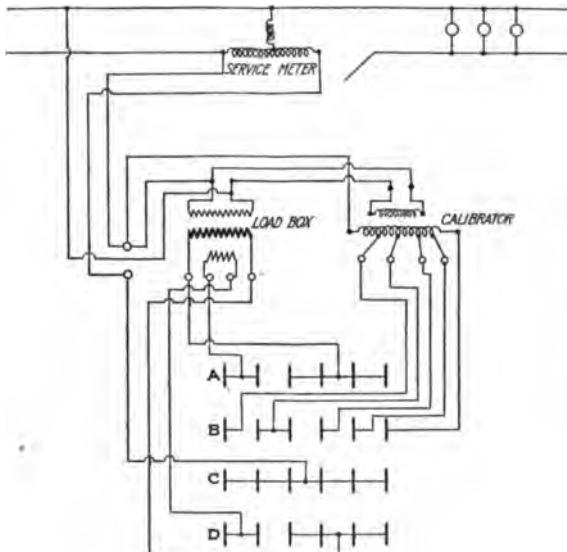


FIG. 61—WIRING DIAGRAM OF COMBINATION LOAD BOX AND CALIBRATOR

to 100 amp. There is a 5-amp. light-load and a 5-amp. heavy-load adjustment.

To use the calibrator alone plug No. 1, shown in the lid of the outfit, is inserted to connect points *B* and *C* on the wiring diagram. To use the load box and the calibrator together plug No. 2 is inserted to connect points *A* and *B* and *C* and *D*. The plugs are inserted through the holes marked 1 to 100, which correspond to the load desired. Spring switch clips are used for making contacts at the points *A*, *B*, *C* and *D*.

To conduct a test with this set, binding posts *A* are first connected with the service meter, a three-conductor cable composed of one potential wire and two current wires being used for all load conditions and tests. The potential connection is made at *P* and the calibrator control switch is connected at *S*. Iron connectors are used at *P* and *S*. By pushing the plug in the side of the pendent switch used with this outfit continuous operation is

permitted. Pushing the end plug, which presses against a spring, causes the calibrator to assume the zero position.

REDUCING THE COST OF SOLDERING

The cost of soldering lugs on cables, leads or armature windings, etc., has been reduced as much as 60 per cent by the Iowa Railway & Light Company of Cedar Rapids by using an acetylene-gas torch for this work instead of molten metal or soldering irons. The gas is purchased in tanks and is conducted to the burner used for melting the solder by means of high-pressure rubber hose. This method permits workmen to reach locations easily which would be almost inaccessible with soldering irons, and thus the labor cost involved in the soldering process is reduced to the minimum.

SPECIAL SWITCH MADE FOR TESTING WATT-HOUR METERS

A convenient method of testing watt-hour meters is indicated in accompanying drawing (Fig. 62), writes R. M. Berry. The

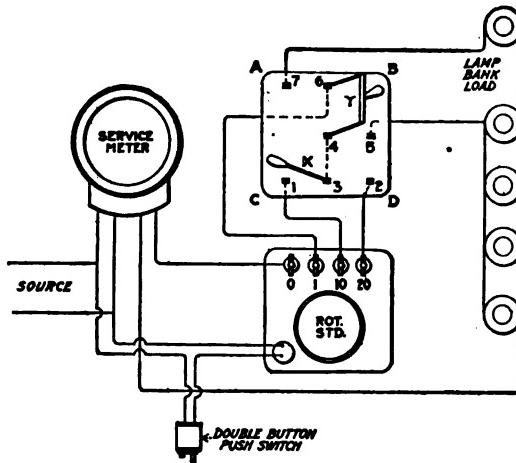


FIG. 62—SPECIAL SWITCH FOR TESTING WATT-HOUR METERS

part of the diagram shown at *ABCD* represents a specially constructed switch for changing the current coils on the rotating

standard without having to remove the wire from one binding post to the other during the period of testing a meter. This switch has been found to be quite a time saver and helps to eliminate mistakes.

The operation of the switch is as follows: For testing with the 20-amp. coil on the rotating standard, adjust the load for 20 amp., throw switches *X* and *Y* toward *BD* and connect points 2 to 3 and 4 to 5 respectively, thus completing the circuit through the 20-amp. coil. In a like manner, for testing with the 10-amp. coil, adjust the load for 10 amp., leave switch *Y* in position *BD* and throw switch *X* toward *AC*, connecting points 1 to 3 and 4 to 5 and completing the circuit through the 10-amp. coil. In testing with the 1-amp. coil switch *Y* is thrown toward *AC*, connecting points 6 to 7 and completing the circuit through the 1-amp. coil.

The idea of having switch *Y* of the construction mentioned is to avoid blowing the fuse on the 1-amp. coil, as only a definite load can be placed on it. When using the other coils the latter is entirely disconnected. This switch was constructed out of fiber board of $\frac{3}{8}$ -in. (3-mm.) thickness for the base and standard knife-switch parts for the contacts. This switch can be mounted in any convenient place for shop testing, or a special cover can be made for the rotating standard deep enough to accommodate the switch when the cover is closed.

SECTION IV

METER READING, BILLING AND BILL DELIVERY, AND COLLECTIONS

CONTINUOUS METER READING

THE Harrisburg (Pa.) Light & Power Company has adopted the continuous meter-reading system which will apply to all electrical consumers and is already in operation. A large amount of work was curtailed in the change-over from the old ledger system, but from now on it will make the work of the cashier and bookkeepers much easier. Another very important result of the change will be that it will produce a far better distribution of the crowd in the company's sales office and bring opportunity for more careful selling methods.

Under the old system, discount day brought a large run on the electric light office and produced so great a crowd that it was practically impossible to bring any selling influence to bear. From now on, however, there will be a limited number of discount takers in the office every day, and it will be possible to discuss the matter of appliances with them. This, it is felt, is certain to produce a large amount of business which otherwise would not be developed.

The Beverly (Mass.) Gas & Electric Company also has adopted the continuous system of reading meters and mailing bills, the new plan being adopted owing to conditions created by the war and the necessity for distributing the work as equally as possible for the meter readers and office staff. Under the old plan the bills were read between the fifteenth and twentieth of each month and were mailed out on the first of the succeeding month.

The city, which has a population of around 20,000, has been divided into about twenty-four districts. The gas and electric meters in the first district are read on the first working day of each month and bills mailed two days later. The meters in the

second district are read on the second working day of each month and bills mailed two days later, the meters in the third district on the third day, and so on. Ten days from the date of mailing bill are allowed in which to secure the discount for prompt payment. Discount dates are plainly stamped on all bills.

DELAYED METER-READING POST CARDS

In order to save the meter readers from the need of making return calls, the Consumers' Electric Light & Power Company of New Orleans, La., has devised a delayed meter-reading post

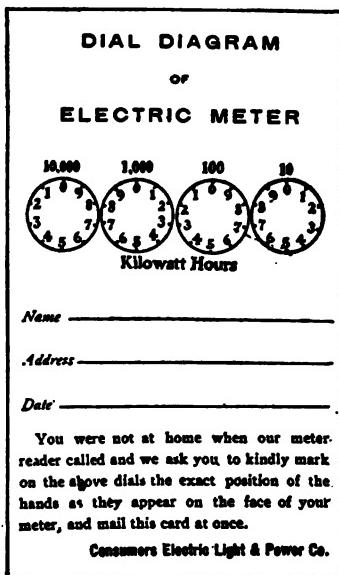


FIG. 63—METER READING POST CARD MAILED BY CUSTOMER

card. If when the meter reader calls he cannot get in, he leaves an addressed government post card, on the reverse side of which is a dial diagram of the meter on which the customer can mark the meter reading, and on which is also a place for the customer's name and address. The customer mails the card and is billed for the amount of energy shown to be used.

This system was put into effect there in January, 1918, and as early as May 75 per cent of the cards left were being returned to the company with readings indicated. In July General Manager W. J. Aicklen stated that through the use of post-card delayed-meter readings the company was effecting a saving of approximately \$50 a month in meter readers' salaries.

Much time is lost by the meter reader through customers not being at home when he calls. In order to get around this difficulty the Twin State Gas-Electric Company of Brattleboro, Vt.,

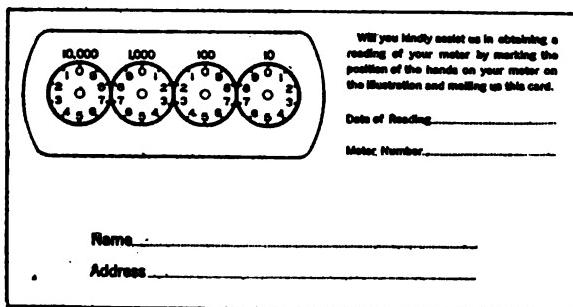


FIG. 64—POST-CARD METER RECORD

asks the customer to read his own meter when the company's reader has not been able to do so on his regular calls.

If the meter reader cannot get in, he slips an addressed post card, like the one shown, under the door or puts it in the mail box. This delayed-meter-reading card requests the customer to mark the position of the hands of the meter on the card and mail it to the company. The same consumer is seldom asked to make his own meter reading for two consecutive months; therefore any inaccuracy in the customer's reading is corrected by the company's man on his following visit. Experience shows that the consumer much prefers this method to having his bill figured on the basis of last year or to being billed for two months next time. Space on the card is provided for the date of reading, the meter number and the name and address of customer.

ECONOMIES OF METER READING AND DELIVERY OF ACCOUNTS

The employment of high-school students in addition to the necessary regular force to read meters and distribute bills to customers has been practiced for several months past by the Sandusky (Ohio) Gas & Electric Company. This system, the company states, is not only materially reducing the expense of reading meters and distributing bills, but in addition makes it possible to reduce the regular operating force to a minimum, as it has been found that where all meters are read between the twentieth of one month and the first of the next it is not always possible to keep the entire force busy during the period from the first to the twentieth of the month, when no outside construction work is under way during the winter months.

BOYS UNSATISFACTORY AS METER READERS

The Topeka (Kan.) Edison Company has discontinued its practice of using boys, picked up as temporary employees, for reading meters. The services of the boys in this respect proved to be unsatisfactory and men are taking their places. The men are being employed permanently and do other work when they are not reading meters. A. H. Purdy, general superintendent of the company, expressed the opinion that the company's experience with boys was unsatisfactory because it is becoming increasingly difficult to secure, for temporary work, boys of the type needed, since so many of them are engaged in other occupations that pay more than a utility company can afford to give for this class of work.

REDUCING THE EXPENSE OF HANDLING ACCOUNTS

The Central Illinois Light Company of Peoria, Ill., has worked out a system for handling customers' accounts that it believes is particularly adapted to fit its conditions. The system contains features, however, that seem also adaptable to the plans of other companies as measures of conservation. The features of the system lie in the combination gas and electric bill and in the machines for handling ledger work.

The company began using its present combination bill in January, 1917, although combination gas and electric billing went into effect in July, 1916. J. H. Thomas, chief clerk for the company, writing concerning this bill, said: "The advantages of the combined bill as I see them are, first, elimination of the sorting of meter-read slips and bills, thus allowing meter readers to give all their time to meter reading and bill distribution; second, ledger keepers are enabled to post credits, make delinquent notices and draw off balances in one-third less time than formerly; third, cashiers are able to handle customers faster, as it is no longer necessary for them to add the gas and electric amounts when the bill goes to the consumer with the net amounts extended. Also the cashiers require one-third less time in adding the coupons than formerly."

Mr. Thomas continued:

In January we replaced our long-hand billing with machine billing, and I consider this a real conservation measure, as our billing force was reduced to one-half of that formerly required. One operator and one stamping clerk now handle 29,000 meters per month. Part of our bills are extended by machine and part by rubber stamps. By test we have proved that extensions may be stamped twice as fast as they could be entered by machine. By analyzing our bills for several months we found that if we used 300 stamps we could stamp about 75 per cent of all extensions; hence our bill design is such that when the consumption in kilowatt-hours or in cubic feet is in excess of fifty (the limit with the stamps) the extension can be completed by machine. From our experience with machine billing we find that a saving of about 30 per cent has been effected in billing expense. The other advantages are a much neater bill and a reduction in the time required between reading and bill delivery.

Our bill is made out directly from the meter-read slip. We do not make a recapitulation sheet or use a carbon-copy ledger; therefore, of course, do not add meter readings, etc., it being the writer's opinion that this checking is nothing short of a "tail wagging the dog" proposition.

On Jan. 1, 1918, we also changed to machine-entered ledgers, and with these were further able to reduce our force. I am of the belief that this ledger installation is the first of its kind. We have used it but a short time, but a thorough preliminary test was given it. Actual working has maintained the results of the test. By its adoption we have been able to reduce ledger costs 30 per cent.

HANDLING BILLING IN A CITY OF 70,000

Two youths aged about eighteen deliver the 23,000 monthly bills of the Kansas Gas & Electric Company at Wichita, a city of 70,000 inhabitants according to the 1910 census. These boys are paid from \$45 to \$50 a month. When they are hired they are told that the position is permanent and affords them an opportunity to work up to the next position, that of meter reader, which pays \$65 a month with a 10 per cent commission on all appliance sales made.

When the bills are ready for delivery they are first routed by

Please Print The Date Billed, Below	
ALWAYS PRESENT THIS CARD WITH PAYMENT	
KANSAS GAS & ELECTRIC COMPANY	
Other Hours 8 a.m. to 8 p.m.	
FLAT RATE	POWER
Light _____ Gas. _____	
Total Flat Rate - COMMERCIAL LIGHTING	
Read _____ Read _____ Consumed _____ K. W. Hrs. 35 K. W. Hrs. at \$16 K. W. Hrs. at 4c	10 K. W. Hrs. at 4c _____ 10 K. W. Hrs. at 4c _____ 10 K. W. Hrs. at 4c _____ 10 K. W. Hrs. at 4c _____ 100 K. W. Hrs. at \$16c _____ 100 K. W. Hrs. at 4c _____ _____ at 4c _____ Total Power _____ Total Flat Rate _____ _____ Total Commercial _____ Total Gross _____ 10 Dues Com. Leg. _____ Net Amount _____
Read _____ Total Commercial _____ Last Settlement or Before _____	

FIG. 65—POST-CARD FORM OF WICHITA (KAN.) COMPANY

an office girl, who at the same time wraps advertising literature around the post card on which the bill itself is made out. This advertising literature is arranged with a 1-in. by 3-in. cut-out so that the customer's name and address on the post card show through the advertising just as the name and address on a letter-head show through the face of a transparent envelope.

This method of combining advertising matter with the bill has been worked out as the Kansas Gas & Electric Company's solution of the problem of using the economical post-card bill and at the same time enjoying the advantage of sending an advertisement with each bill. The cost of this advertising alone is about \$60 per month. Since the United States entered the war the company has made it a practice to include patriotic advertising in support of the Red Cross, the Liberty loan, "smileage books,"

etc., on one side of its leaflet while using the other side for promoting the use of electrical appliances.

LARGE SAVING BY MACHINE BILLING

About one year ago the Commonwealth Edison Company of Chicago made a trial installation of twelve Elliott Fisher adding typewriters. With these machines the company handled 20 per cent of its accounts. In using these machines the operator, working directly from the meter-reading book, makes out the bill, posts the ledger, and makes a recapitulation sheet, all at one operation, the entry in the ledger and on the recapitulation sheet being a carbon copy of the bill. On each machine there is a totalizer, or adding machine, on each column. For instance, there is one on both the present and previous wattmeter reading; there is one on the kilowatt-hours used, on the gross bill, discount, net bill, etc., and in addition there is a cross-footing mechanism and totalizer which subtracts one reading from the other, showing the net difference; which distributes the kilowatt-hours at the various rates and subtracts the discount from the gross, giving the net bill. Fig. 67 is an illustration of the ledger sheet and bill form. All the dates and the name and address are put on the bill in one operation by the addressograph machine.

The recapitulation sheet (Fig. 66) is used for several purposes: (1) For checking the extension and correctness of the bill; (2) to obtain the total of the monthly billing; (3) to obtain the totals of the number of customers, kilowatt-hours, and other statistics; (4) to furnish an analysis of output and earnings by rate schedules; (5) for drawing off various other statistics.

Recently the company, finding the trial installation satisfactory, purchased eighteen more machines, bringing its total equipment up to thirty machines. From its experience with the machines the company finds that a saving of 20 per cent on billing costs can be effected over the old "longhand" method of billing. When it is stated that each bill issued by the company costs about 16 cents the extent of this saving can be better appreciated.

Further advantages of the mechanical billing system are that the bills look neater and can be turned out faster. It is possible to reduce by one-third the time that formerly elapsed between

STATISTICAL GROUP	DATE	enrolment in BUCHOLZ										C.R. 1									
		white	black	total	white	black	total	white	black	total	white	white	black	total	white	black	total	white	black	total	
	1942	1934	49	15	64	2.94	.36	3.30	2.64	.36	2.94	2.36	.36	2.70	2.36	.36	2.64	2.36	.36	2.70	2.36
	1423	1497	36	15	51	1.56	.16	1.72	1.40	.16	1.56	1.36	.16	1.50	1.36	.16	1.50	1.36	.16	1.50	1.36
	1738	1706	26	15	41	2.46	.26	2.72	2.16	.26	2.46	2.26	.26	2.26	2.06	.26	2.26	2.06	.26	2.26	2.06
	0359	0317	35	13	48	1.20	.13	1.33	1.17	.13	1.20	1.17	.13	1.17	1.17	.13	1.17	1.17	.13	1.17	1.17
	0935	0982	23	13	36	1.34	.19	1.53	1.35	.19	1.34	1.35	.19	1.35	1.35	.19	1.35	1.35	.19	1.35	1.35
	0503	0490	9	9	18	0.90	.09	0.99	0.85	.09	0.90	0.85	.09	0.85	0.85	.09	0.85	0.85	.09	0.85	0.85
	0128	0109	19	10	29	1.00	.50	1.50	1.00	.50	1.00	1.00	.50	1.00	1.00	.50	1.00	1.00	.50	1.00	1.00
	0074	0051	25	20	45	2.18	.20	2.38	2.10	.20	2.18	2.10	.20	2.10	2.10	.20	2.10	2.10	.20	2.10	2.10
	0846	0853	31	29	60	2.00	.29	2.29	2.00	.29	2.00	2.00	.29	2.00	2.00	.29	2.00	2.00	.29	2.00	2.00
	0558	0542	24	21	45	2.00	.21	2.21	2.00	.21	2.00	2.00	.21	2.00	2.00	.21	2.00	2.00	.21	2.00	2.00
	1065	1042	25	21	46	2.22	.21	2.43	2.22	.21	2.22	2.22	.21	2.22	2.22	.21	2.22	2.22	.21	2.22	2.22
	0733	0733	20	18	38	1.00	.18	1.18	1.00	.18	1.00	1.00	.18	1.00	1.00	.18	1.00	1.00	.18	1.00	1.00
	1045	0590	53	16	69	1.50	.16	1.66	1.50	.16	1.50	1.50	.16	1.50	1.50	.16	1.50	1.50	.16	1.50	1.50
	0383	0363	16	—	16	1.00	—	1.00	1.00	—	1.00	1.00	—	1.00	1.00	—	1.00	1.00	—	1.00	1.00
	1433	1410	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2340	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	0847	0847	21	11	32	1.66	.11	1.77	1.66	.11	1.66	1.66	.11	1.66	1.66	.11	1.66	1.66	.11	1.66	1.66
	0837	0870	22	16	38	1.10	.16	1.26	1.10	.16	1.10	1.10	.16	1.10	1.10	.16	1.10	1.10	.16	1.10	1.10
	0519	0502	17	17	34	2.04	.17	2.21	2.04	.17	2.04	2.04	.17	2.04	2.04	.17	2.04	2.04	.17	2.04	2.04
	02105	02105	2132	2132	4264	565	565	620	565	565	620	620	565	620	620	565	620	565	620	565	620

FIG. 66—RECAPITULATION SHEET OF COMMONWEALTH EDISON COMPANY

FIG. 67.—LEDGER SHEET AND BILL OF COMMONWEALTH EDISON COMPANY

the date of meter reading and the date of delivery of the bill. It was at first thought that men would be required to operate the machines. Experience has shown, however, that young women with a high-school education can easily and quickly become proficient operators.

A BILLING PLAN THAT HASTENS COLLECTIONS

The Hydro-Electric Light & Power Company of Connersville, Ind., has a billing system by which the men who do the meter reading at the same time make out the bills and leave them on

FIG. 68—THE THREE BILL FORMS USED BY INDIANA CENTRAL-STATION COMPANY

the consumers' premises. The company supplies electric light and power service as well as gas in Connersville, which has a population of 8000, and also supplies electric service to several small towns near by. The general form of bills is the same for each class of service, namely, electric light, electric power, electric service in nearby towns, and gas. The bills differ somewhat,

however, in detail. The three types of electric bills, which the company designates as forms Nos. 107, 108 and 109, are shown in Fig. 68. Form No. 107 is the regular lighting bill, form No. 108 is the regular power bill, and form No. 109 is the bill which is used for small towns where collections are made through the banks. The system as it applies to form No. 107 is as follows:

The bills are made in triplicate and are perforated for easy detachment. An addressograph is used to fill in the name, address and date. The last readings and any balances are then put on. The meter readers aim to read 100 bills each half day and have ring binders which will take care of that number of bills. As they read a meter they make out the bill and leave the third copy, bringing back to the office the copies marked "File" and "Receipt." Postings are then made, and the bills are distributed in an office rack for payment.

When payment is made the customer is supposed to bring with him the third copy. This gives the account number, which is also put on by the addressograph along with the name, etc. This plan facilitates the locating of the original bill, but, of course, is not absolutely necessary. The company's cash register prints the receipt on the right end of the customer's copy, showing who receives the payment, the account it goes to, the amount, the transaction number and the date. The same information is also shown on the margin of the company's own copy, which is filed for future reference.

The same system applies to the power and gas bills, but the form No. 109 used in small towns is slightly different. The difference is that the customer brings back his notice to be receipted, whereas for the city customer the second office copy is receipted. In the small town meter readers leave one notice at the house, a second notice at the bank and bring back the first copy to the office.

In response to a query about the cost of operating this system, Erle G. Weeks, treasurer of the company, said: "I have no absolute costs, but our men can read 200 meters a day. This gives an idea of what the cost would be. We consider that the expense of getting the bills ready would be no more than that of any other form of billing.

"There are several very distinct advantages in the use of these bills. First is the saving of postage. Second is the fact that

the customer can come in and pay his bill just as soon as the meter is read. There are many cases where the customer comes into the office to pay his bill before the meter reader returns after the half day, and since the customer has his own copy of the bill we take his money and get the benefit of the use of it. During these days of close figuring we feel that this early collection is worth something.

"Then, again, we have the use of the advertising on the back of the bills. This is not a big expense, and the announcements go to every customer, giving us an opportunity of pushing a special item each month. The copies shown, however, can hardly be said to carry an advertisement. We wanted to urge prompt payment."

RUBBER STAMPS SAVE EXPENSE

The Consumers' Electric Light & Power Company of New Orleans has introduced a system of rubber stamps to save some

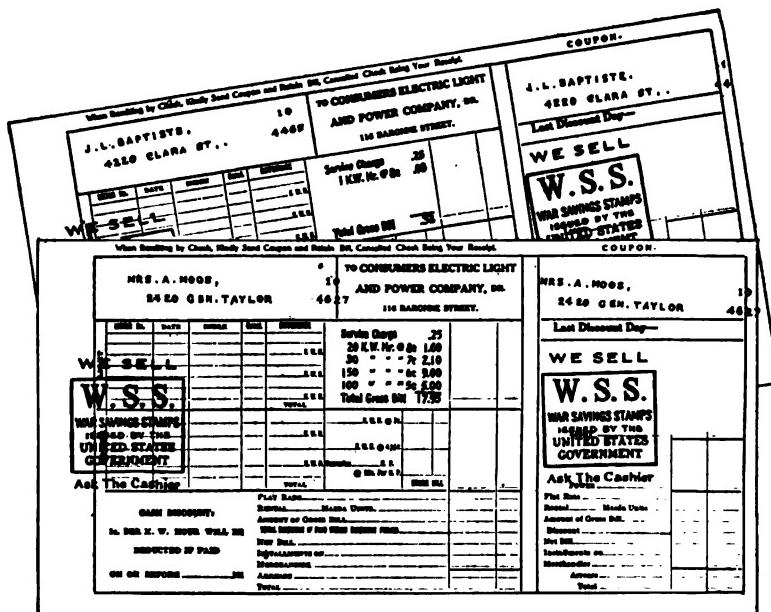


FIG. 69—HOW PUBLIC UTILITY USES RUBBER STAMPS TO SAVE BILLING EXPENSE

of the clerical work entailed in making out its several thousand monthly bills. Under the company's rate lighting service is

figured on a sliding scale and a great deal of calculating is required in figuring the bill totals each month. To make out a bill for 300 kw.-hr., for instance, it has been necessary to list five amounts and the total, including, first, the service charge of 25 cents; second, the first 20 kw.-hr. at 8 cents; then the next 30 kw.-hr. at 7 cents; then the next 150 kw.-hr. at 6 cents, and the final 100 kw.-hr. at 5 cents. These extensions must then be totaled.

A careful analysis of the bills developed the fact that 80 per cent of the customers were using somewhere from 1 kw.-hr. to 300 kw.-hr. per month, and a series of rubber stamps were secured numbered from 1 to 300, each of which bears the necessary calculation to cover that consumption. So that by merely stamping the bill the fixed service charge of 25 cents, which is added to all retail bills, and all the items on the sliding scale are covered in one operation. The billing clerk has these 300 stamps before him arranged in a handy rack, from which he can easily pick the proper stamp with far less risk of error than in hasty figuring. The only figuring now necessary on the bill in pen and ink is the discount allowed for prompt payment, a simple matter as 1 cent is allowed for each kilowatt-hour consumed during the month.

It has been found that the use of these stamps makes it possible to do the billing in one-third of the time formerly required, and with considerable more neatness, besides minimizing the element of incorrectness in totaling. General Manager Aicklen recommends this system to other managers and offers to send a full set of impressions from these stamps to any one who desires them.

POSTAL CARDS FOR BILLING

In many ways government postal cards present a means of saving in billing. For one thing, the stock costs nothing. A number of central stations have come around to the use of postal cards for bills. The Oklahoma Gas & Electric Company at Kiefer and the Sapulpa (Okla.) Electric Company, under the management of H. M. Byllesby & Company, use similar cards, as shown in Fig. 70. Dates and the space to the right are in red and are changed each month, and the space at the left is used for advertisements and announcements.

CUTTING CENTRAL STATION COSTS

TO OKLAHOMA GAS & ELECTRIC CO. DR. KIEFER, OKLAHOMA		SEC. _____ LINE _____
ELECTRIC CURRENT FOR DECEMBER 1917		DEC. 1917 KIEFER, OKLA.
<p style="text-align: center;">Our Wish for You A Very Prosperous New Year</p>	DEC.	READING_____KWH
	NOV.	READING_____KWH
	CONSUMPTION _____ KWH	
	DISCOUNT 10 PER CENT IF PAID ON OR BEFORE JAN. 10, 1918	
	NET AMOUNT	
MINIMUM BILL. NO DISCOUNT		
DELINQUENT BILL. NO DISCOUNT		
TOTAL		
<p>BRING THIS CARD, PLEASE, TO BE RECEIVED <small>FAILURE TO RECEIVE BILL DOES NOT ENTITLE CONSUMER TO DISCOUNT AMONIUM FTS OR SAMPSON</small></p>		
		GOOD SERVICE TO ALL CONSUMERS
		SEND THIS STUB WHEN YOU REMIT BY CHECK

FIG. 70—POSTAL CARD BILLS HAVE THEIR OWN ADVANTAGES

GAS AND ELECTRIC BILLS ON SAME POST CARD

While the post-card bill has been used rather extensively by both gas companies and electric companies, it is rather unusual to find a combination gas and electric company placing both

TO FORT SMITH LIGHT & TRACTION CO. DR. FORT SMITH AND VAN BUREN, ARK.		APRIL, 1918	APRIL, 1918
GAS:		GAS	GAS
April.....	Reading-----		
March.....	Reading-----		
Cubic Feet Used	600 Net		
<small>Should information be desired and 17-cent rate apply, per unit be enclosed to a return on this bill of - \$.5</small>			
ELECTRIC:		ELECTRIC	ELECTRIC
April.....	Reading-----		
March.....	Reading-----	Gross	
Difference	-----	Disc.	
X	-----	K.W. H. Used Net	
Previous Balance			
TOTAL			
<p>To receive discount, bills must be paid on or before the 10th of month following that in which service is rendered. Failure to receive bill does not entitle consumer to discount.</p> <p>PLEASE BRING THIS CARD</p>			
<small>Mail this card with check</small>			

FIG. 71—COMBINATION BILL OF ARKANSAS COMPANY

electric and gas bills on the same post card. This practice, however, has been resorted to by the Fort Smith (Ark.) Light & Traction Company in an effort to keep its billing costs as low as possible. The accompanying illustration (Fig. 71) shows how the readings and the items indicating cost of service are arranged on the card. It is the intention of the auditing department of the company to add a place on this post-card bill later for merchandise accounts, thus further reducing the number of different

forms used by the company to cut down billing expense. The company has about 4010 electric meters and 6459 gas meters, making a total of 10,469 meters in service in the two cities of Fort Smith and Van Buren which it serves.

RECENT METHODS OF BILL DELIVERY

With the thought and energy of every central station concentrated as never before on measures of economy, a great many companies have turned a searching eye on their methods of delivering the monthly statement. The increase in the postal rates has brought a considerable additional cost in many cases, and the loss of men into the national service has generally reduced the organization available for carrying on routine work of this kind.

When the postage rate went up, of course, the idea of discontinuing the mailing of the monthly service bills and delivering them instead naturally suggested itself. There is more than the question of cost involved, however, for the mailing of a bill is generally conceded to be satisfactory proof of its delivery. Moreover, if delivered by hand, should this be done by meter readers, high-school boys, old men, girls or women? Or, if mailed, which is the better—post-card or regular bill inclosed in envelope? These questions are particularly pertinent and worth consideration by every central station.

Not long ago—but before the postal rates went up—the Cleveland Electric Illuminating Company made an analysis of the cost of its bill delivery, which includes 60,000 bills delivered by hand and 40,000 by mail, to find out how much could be saved by using a post-card bill. The figures were found to be as shown in the accompanying table.

With the 1-cent postage rate the post-card proved to be the cheaper method, but the doubling of this cost made the hand-delivery system far more economical. The system in Cleveland has been to place the delivered bill in the consumer's mail box, or if there is no box to hand it to a member of the family. Failing this, the distributor brings back the bill and it is mailed. For this delivery the Cleveland company first tried boys sixteen or eighteen years old, but did not find them satisfactory. It then employed elderly men of from fifty to sixty-five years and has practically eliminated all complaints.

In Sandusky, Ohio, however, the Sandusky, Gas & Electric Company has had most satisfactory results from high-school boys, who both read the meters and deliver the bills. The boys receive 1 cent per meter read. Before the postal rate went up the company used government post cards, but since then it has devised a card of the same size, of which a six months' supply can be printed in advance. These are stamped and mailed to customers beyond the convenient reach of the delivery routes, but the bulk

COMPARISON OF COST OF PRESENT SYSTEM OF HANDLING 100,000 CONSUMERS' BILLS PER MONTH WITH PROPOSED SPECIAL CARD OR GOVERNMENT 1-CENT POST-CARD SYSTEM, AT CLEVELAND, OHIO

Present system, printed bill in outlook envelope; 60,000 delivered by company distributors, 40,000 mailed with 2-cent stamps.

PRESENT SYSTEM:

100,000 bills, at \$1.50 per 1000.....	\$150.00
100,000 outlook envelopes, at \$1.65 per 1000.....	165.00
40,000 2-cent stamps in rolls	802.40
Inclosing bills in envelopes—2 boys one month at \$40 each	80.00
Sealing 100,000 envelopes and affixing 40,000 stamps, one boy one month.....	45.00
✓ Sorting 60,000 bills for delivery, one boy one month..	40.00
✓ Delivering 60,000 bills, five men at \$70 per month....	350.00
Supervising delivery, half time of one man at \$100....	50.00
 Total	 \$1,682.40

PROPOSED SYSTEM:

Special Cards, 1-Cent Post Stamp Affixed:

100,000 cards, printed	\$116.00
Affixing stamps, one boy one month.....	45.00
100,000, 1-cent stamps, in rolls	1,006.00

Total	1,167.00
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Amount saved by using special cards and affixing stamps	\$515.40
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Government 1-Cent Post Cards:

100,000 cards	\$1,000.00
Printing	25.84

Total	\$1,025.84
Additional saving with government cards.....	141.16

Amount saved by using government stamped cards	\$656.56
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Items checked ✓ indicate expense of delivering 60,000 bills per month. To find total delivery expense on 100,000 bills, add item No. 3, 40,000 2-cent stamps, \$802.40.

of them the boys deliver at a cost so far of approximately a half cent per bill. This the company finds is effecting a saving of \$18 per 1000 customers per month on postage alone and is bringing additional economy by reducing the operating force to a minimum during the winter. Because of the limited number of hours that the students have available for this work, it is necessary to employ a much larger number than if the regular employees were handling it, but this has not proved an objection. About 9000 bills are delivered in Sandusky between the twentieth and the last of each month.

In Mobile, Ala., the company now delivers by hand at a cost of about 1½ cents per bill, a saving of about \$37.50 a month since the postal increase. In Traverse City, Mich., the company delivers to about 1400 consumers at a cost of 1 cent, and this also includes collecting about one-third of the accounts. In Pine Bluff, Ark., the company delivers 4500 bills, using the regular meter readers after the readings are completed. It requires from four to five days and costs in all, it is figured, from \$10.50 to \$12.50. In Kokomo, Ind., the company has also changed from mailing to delivery and is distributing 6000 bills by meter readers at a cost of \$35. In Kingston, N. Y., the meter readers now deliver 5800 gas and electric bills, all except about 300 which are mailed to outlying territory, and the company finds the system quite as dependable as by mail. It saves approximately \$50 every month. In Indianapolis the meter-men of the Merchants' Heat & Light Company read meters every morning and deliver bills in the afternoon, and they have proved much more responsible than schoolboys, though boys were tried. The cost per bill now figures about 1 cent. In Denver the bills are mailed to the suburbs but delivered in the city by boys and young men on bicycles at a cost of one-third of a cent per bill.

In Wilkes-Barre, Pa., 19,500 bills—gas, electric and steam heat—are delivered by two men, who receive \$65 per month, delivering continuously, which means a cost of about one-half cent per bill. These men collect when possible as they deliver. In Terre Haute, Ind., the company formerly had mailed all bills at a total cost of \$125 monthly, but with the higher postal rate began delivering all bills within the city by one man, who is paid \$45. The remaining postage cost for bills still mailed is also \$45, so that in spite of higher postage the company is saving \$35 monthly.

The consensus of opinion, therefore, judged from the experience of these and a large number of other cities heard from, would clearly recommend the delivery of bills within the centers of dense population. One Pennsylvania company, moreover, which operates through an extensive rural territory serving about 75,000 population, is delivering all bills in spite of distances, and claims a delivery cost of 0.92 cent per bill on a total of 7016 bills. This company lays much stress at the same time on the value of the collectors in maintaining good relations with the consumer, a point which is echoed by a number of other companies. Men are picked who do their work in a friendly spirit, and much good comes of it.

On the other hand, in many outlying towns in Indiana the Indiana Railways & Light Company began with this year to try the plan of not sending any bills at all to some 2000 customers, who are asked to call at the local offices to pay their bills, though delinquency notices are still mailed when necessary. In line with this, in Brattleboro, Va.; in Franklin, Ind., and in Seymour, Ind., the local utilities have been furnishing many customers with cards on which to make their own meter readings. This method has met with considerable success. In Fort Madison, Iowa, the meter reader in certain residence districts carries with him bills already partly made out, on which he enters the reading, making out the bill and presenting it for collection at the one call. The company's other bills go out on post cards, and, in short, since the rates went up there has been a decided movement in the industry toward the post-card bill as offering an appropriate war-time economy.

Few Companies Using Women. All in all, however, the trend is toward delivery, if not by meter reader, then by boys or old men. One New England central station has found a practical solution by making use of the services of the substitute postmen, who, though on waiting orders, are familiar with the town and have received instructions in delivering. Everywhere the possible expedient of utilizing women for delivering has been considered, but apparently it has not been adopted very largely. However, El Reno, Okla., reports the bill delivery in charge of two young women, who are taking care of it well and at a saving of \$30 monthly on postage. At Binghamton, N. Y., girls are used to read meters and deliver bills.

Of course, the many cities where bills have always been mailed at the 2-cent rate are not affected by the postal increase. Buffalo and Wilmington, Del., state that they have no intention of changing, for they consider mailing less trouble and more sure. In Detroit, on the other hand, the company has been delivering bills by messenger for years at a cost much less than postage, the meter readers delivering the bills. In Providence, R. I., the method is optional with the consumer in most districts. He may have it by mail or messenger, as he prefers, and bills for suburban towns are delivered to the suburban post offices and mailed there under the local rate. There is plainly enough diversity, therefore, to suggest the advisability of every man looking well to his own conditions locally; but in the majority of cases delivery seems to be the preferred method.

ECONOMY IN BILL DELIVERY

Phases of operation, such as the distribution of statements, which during pre-war periods received only passing attention, are demanding greater consideration, writes O. M. Booher, chairman commercial section Indiana Electric Light Association. All unnecessary expense is being eliminated and all necessary expense is being reduced. Long-established customs are now giving ground to different and more economical methods. This is especially true in the distribution of bills. During the pre-war period a very large percentage of this work was handled by mail; to-day many companies ask their patrons to call at the office for their statements, and many others deliver their statements in person. Most of these changes of methods have taken place at least since the recent increase in postal rates.

The acid test of a plan is the way it works out in practice. From the standpoint of economy a certain arrangement may be fine and at the same time prove to be very impracticable from other angles. Considering the plan of bill delivering in person, there arises the complaints from customers who are displeased because of not receiving the statement regularly or receiving the wrong statement, etc. Another phase of this plan which must be considered is the general public opinion regarding the evasion of the war revenue which would be derived from the increase in postal rates.

The Indiana Railways & Light Company believes the saving effected by personal delivery more than offsets a few scattered criticisms and complaints which are heard from time to time from the customers. During the pre-war period it was mailing its bills for the exact cost of \$11 per 1000. This includes postal cards and printing. It is to-day delivering in person at a cost of \$10.60 per 1000, including paper stock, printing and labor. Had it continued to send its statements out by mail the cost would be \$21 per 1000. In other words, the company is saving \$10.40 per 1000, and for 8000 accounts a saving is realized of \$83.20 per month, or approximately \$1,000 per annum. The labor item figures 0.74 cents per statement delivered. The statements are delivered by the metermen.

Mr. Booher is of the opinion that, considering the utility as a highly important war-time essential, the operators are performing a patriotic duty in trying to maintain financial equilibrium in order that the utility may continue to remain a valuable war asset. And if \$1,000 per year can be saved by changing this or that operating plan, the change should be made, for such a change would be more in keeping with the general war program than the purchase of a few postage stamps, which net the government an infinitesimal profit.

Questionnaires were forwarded to forty-three leading member companies of the Indiana Electric Light Association, representing fifty-six different properties. Twenty-eight replies, representing thirty-nine properties, were received. The first question was, "Do you deliver by mail, in person, or are bills held at office?" There were thirty-four replies, divided as follows: By person, 15; by mail, 8; bills held at office, 11. One reported that bills were made out and left by readers. Question number two asked for the cost per statement delivered by person. There were twelve answers. The average was 0.89 cent each. Question number three asked, "Do you have many complaints from customers where bills are delivered in person?" All answered, "A few." In seven cases the meter readers did the delivering, in two cases office clerks, in two cases young boys, and in one case an office girl. It is of interest to note that where boys were used the cost per statement averaged only 0.49 cent each.

Because of the scarcity of men no doubt many companies which deliver the bills in person are considering the employment of

women. So far as is known, this arrangement is not in use at this time to any extended degree. When the time comes there is no doubt that women will prove capable not only to deliver statements but to read and test meters and perform many other similar duties. Another plan which might be considered is that of placing bill delivery in the hands of outside agents. In some cases agents may contract with all other local utilities for the performance of this duty and consequently be able to make a very attractive price. Mr. Booher feels, however, that the work should be done by men inside of the company in order that all irregularities may be properly looked after. From the replies received from the various companies regarding bill distribution it would appear that this question has not received proper consideration in some cases, or that there exists a wide difference of opinion.

"CASH-AND-CARRY" PLAN APPLIED TO LIGHT BILLS

Lighting companies operating in small communities have been under a greater comparative strain during the past two years than those operating in larger places. With little opportunity to increase their load, with fixed rates and the increasing cost of

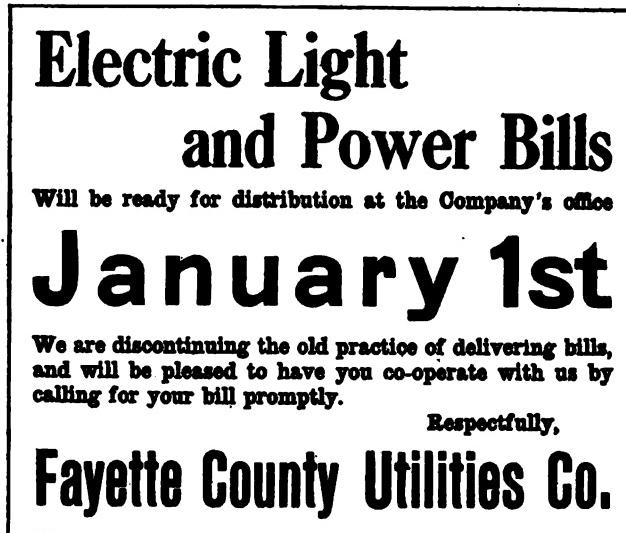


FIG. 72—ADVERTISEMENT USED TO ANNOUNCE CHANGE IN BILLING METHOD

operation, these small companies, which never did as a class enjoy an enviable net profit, have been hard pushed these days to show any profit at all. To prevent disaster economies must be put into practice wherever possible. A single example of an economical measure particularly adaptable to the small-town property is outlined below. It is a method for cutting the cost of billing.

Several subsidiaries of the Utilities Development Corporation of Chicago have discontinued their old practice of distributing or mailing bills for electric service to consumers. Instead they now advertise that the bills are ready for distribution at the company's office and request customers to call for them. The companies which have tried the plan, according to Miss L. M. Beefield of the Utilities Development Corporation, are enthusiastic over its success.

The Fayette County Utilities Company, Oelwein, Iowa, one of the subsidiaries using the plan, reports that in November the expense of sending out the bills was approximately \$18.65 under the former method, and this represented the situation generally throughout the industry. This figure included payment of 1 cent per bill to the high-school boy who delivered the majority of the bills, besides the cost of envelopes, labor of folding, inclosing, sealing and stamping the remainder, plus postage. In December, under the new system, the expense was only \$7.50, namely \$2 for the advertisement and \$5 for postage on the bills which were not called for, plus about 50 cents for the envelopes. Seventy-five per cent of the bills were called for by Jan. 15 after the advertisement (Fig. 72) that made the announcement as of Jan. 1. A far greater proportion of bills called for is expected in succeeding months, inasmuch as many customers failed to notice the advertisement and were awaiting the receipt of their bills by carrier.

In commenting on the plan the Oelwein company stated: "As a labor-saver the plan is a wonder. It does away with the folding and inclosing of the bills, together with the sealing and stamping of envelopes, and we certainly appreciate this extra time along about the latter part of the month!"

In trying out this plan, however, a word of caution is necessary. If a customer does not call for his statement, he should be billed. Otherwise a customer might get two or three months in arrears and find it difficult to make a settlement. In such a case

not only does the company stand to take a loss which might wipe out the saving of a whole month but it is also likely to make an enemy.

SPEEDING UP COLLECTIONS

It appears the question of collections looms large, particularly at this time, when every dollar must be worked and worked to the limit, writes O. M. Booher, chairman commercial section Indiana Electric Light Association. The usual custom of having the local central station serve its community in the capacity of a bank, without proper banking rules and regulations, is poor business, even when money is easy. The tightening up of money naturally should lead the central station to think of means to hasten collections. The practice of time payments on merchandise and miscellaneous sales accounts should be either entirely eliminated or greatly reduced unless a fair rate of interest is collected or unless the sales profits are amply sufficient to warrant time payments.

Reconnection Charge Should Be Enforced. All companies should establish and enforce without discrimination certain penalties for non-payment. In extreme cases, where disconnections are necessary, a charge for reconnection is not out of place if the "chronics" are to be eliminated. There has been enforced in Kokomo, Ind., a reconnection charge of \$1 and it is found that it adds materially to collections as a whole, helping to reduce non-collectibles to less than 0.5 per cent. Little adverse public comment is caused by this practice.

Another feasible plan which is working out successfully, especially with the larger companies, is the establishment of authorized agencies in each small community center where all bills save those in dispute or in arrears may be paid. Such a

REPLIES TO QUESTIONS ASKED OF FORTY-EIGHT ELECTRIC COMPANIES

	Number Answering	Yes	No	Average of Answers
Do you allow cash discount	37	28	9	...
Do you send out delinquent notices...	36	30	6	...
Do you discount for non-payment after a certain date	36	34	2	...
Do you charge for reconnection.....	38	17	21	...
Per cent. of bills collected during dis- count period	31	..	..	78.5
Per cent. receiving delinquent notices	30	..	..	11.2
Per cent. of total monthly receipts considered non-collectible	24	..	..	0.87

system adds much to the convenience of the customer and speeds up collections considerably. At the same time it creates public good will.

The question of collections is closely affiliated with public policy. Labor is scarce and its scarcity is increasing, consequently labor is growing much more independent. A man can be loyal to his company or disloyal as he chooses. He can get a job just as good, or maybe a little better, somewhere else. Therefore great care should be exercised in the selection of a man to place in charge of collections, so as to be sure that the company's interest will be carefully looked after. The customer should not be antagonized or insulted because he is a little late paying his bills. In other words, proper discretion should be exercised, and this will not be done unless a man of acquaintance and one who is in touch with the public pulse be employed.

How Thirty Indiana Companies Do It. In order to summarize the collection practice of a number of companies letters were sent to forty-eight members of the Indiana Electric Light Association. The replies received are reviewed in the table here-with. These replies show that a majority of companies favor allowing cash discount, sending out delinquent notices and disconnecting promptly for non-payment. Opinion seems to be about equally divided for and against a charge for reconnection. The replies also show that 78.5 per cent of the customers take advantage of cash discounts and 11.2 per cent wait to receive delinquent notices. The average of accounts considered non-collectible amounts to the surprisingly high figure of 0.87 per cent.

The letters also brought out that in thirty-one companies the collections are looked after as follows: Two companies by manager of collections, five companies by chief clerk, eight companies by cashier, two companies by auditor, seven companies by office force, six companies by general manager, and one company by treasurer. In most cases the same individual looks after collections of accounts for merchandise, motors and signs as well as customers' monthly accounts for energy consumed.

GRANTING CREDIT

When every dollar means so much, when losses must be minimized, the necessity for stricter credits becomes apparent. The credit department of a central-station company therefore occupies a much more important position than formerly. Strict methods calculated to keep down losses are all the more desirable. Such methods are outlined in the following statement showing how a large Middle Western utility takes care of its customers' credits.

Two Classes of Contracts. Commercial contracts are received in the credit department from the contract department, and on receipt are stamped on a receiving time stamp showing the exact time of arrival in the department. They are then checked off in a receiving book, which is an index as to whether or not the contracts have been received or are being held in the department. The credit slip attached to each contract then receives a number similar to the contract, by which it can be identified later on should it become necessary to refer to it. After a careful examination of the signature on each is made, the contracts, which may be divided as class 1 and class 2, are handled in the following manner:

Class 1—Applications from those claiming to be former consumers and giving address of former location as reference. The account is looked up to ascertain the customer's habit of pay and to find out whether the account is paid up to date. If the investigation proves satisfactory, the application is passed without further delay. If, however, the customer has paid penalty month after month, or if it has been necessary to cut off his service in order to force payment, a deposit for the new address is required.

When a deposit is necessary the customer is so notified by letter and the application is held pending its receipt. Upon receipt of the deposit a deposit certificate is issued and mailed to the depositor and the application is approved for service. When more than the current bills at the previous address are found owing a statement is sent the customer, with a letter notifying him that no service will be given until payment is made. The account in arrears is noted "Notify credit department when paid," so that in the event of the payment crossing the letter in the mail, the

bookkeeper will advise of receipt of payment at once and thus avoid unnecessary delay. The application is filed in the holding file, and no service given, until account is paid.

Class 2—Applications from those claiming never to have used company's service. This class of applications is looked up in the suspense file to ascertain whether the applicant has not overlooked a previous address where service has been used and a balance remains unpaid. If the suspense file discloses such an account, the applicant is advised by letter of such indebtedness and payment requested, the application being held and no service given until payment is made.

Duplicate Copies of Applications. When the suspense account discloses no indebtedness, rating books are consulted, in some cases special reports from the rating agencies are obtained, or references offered as to the responsibility and credit standing of the applicant are investigated. Should the investigation prove unsatisfactory, a deposit is requested which is equal to two months' bills, the amount of the bills being estimated by installation, location and class of business. This deposit is requested by letter and the application filed in the holding file until received.

Owners of real estate in good standing are passed after claim of ownership has been verified. Applicants who object to making a cash deposit can furnish a guarantee from a real estate owner in good standing, or from a responsible business man, guarantor being required to sign a form adopted for this purpose.

A duplicate copy of all resident applications taken in the contract department is received in the credit department each morning. On these applications the service has been given before the credit has been passed so as not to inconvenience the applicant while credit is being investigated. On receipt of these duplicate copies of the application the same routine is followed as with the commercial contracts. When deposits are required which the applicant refuses to pay service is disconnected and the meter removed in a manner to be explained further along.

All letters requesting a deposit or unpaid balance have two carbon copies. One of these copies is attached to the application and filed in the holding file and the other is filed in an every-day file seven days after date. When these copies are reached they are checked with the holding file, and in all cases

where the request has been complied with the copies are destroyed, but those from whom there has been no reply receive a second letter calling attention to the first one and requesting a reply. These second letters also have two copies, one of which is attached to the application and returned to the holding file, and the other placed in the every-day file seven days ahead. If no response is had to this letter at the end of seven days, the application is removed from the file, and if the applicant has no service at the new address it is canceled and returned to the contract department.

Where a deposit is found to be necessary from applicants for commercial lighting who move into a location where light is already installed and in use, and for all resident applications where service has been turned on before credit is investigated, a shut-off notice is made out at the time the first deposit letter is written. This shut-off order instructs the shut-off collector to call and obtain the deposit or disconnect the service. When the collector calls, unless deposit is received or a good reason given for its not being made, or satisfactory information as to the applicant's credit standing given, service is discontinued. These cut-offs are held ten days, and if the applicant does not call or make some attempt to satisfy credit, the meter is ordered removed. When the repair department reports back that the meter has been removed the application is canceled and returned to the contract department.

In all cases where commercial applications are held in the credit department the contract department is notified at once why application is being held, and in cases where the applicant is the successor and the service has not been discontinued for the predecessor a status slip accompanies the notice requesting that the successor be billed from the date of his application.

When a final bill is rendered and not paid a statement is made out in duplicate by the collection department and a duplicate copy is sent to the credit department, where a record is taken of it on a card and the card then filed in the suspense file. Where the delinquent is a corporation or partnership the credit slip received with the contract is referred to, and the officers' or partners' names and addresses are ascertained and a card made in each of their names, with a notation thereon to refer to the card for the company of which they are members. The dupli-

cate statement is then stamped "Suspense" and returned to the district head in charge of collections, to be used as a check on the collector. The statement is then worked by the collector, and a report of his calls and their results is noted on the reverse side. Should the statement be collected or paid at the office, the statement is returned to the credit department so noted, and the card is withdrawn from the suspense file and destroyed. Should the account prove uncollectible and it be found necessary to send to an attorney, the statement of the collector, with his reports noted thereon, is returned to the credit department and any information of value obtained by the collector is transferred to the suspense card to aid in the collection of the account later if opportunity arise.

The value of the suspense file depends in large measure on obtaining the applicant's full first name. If the customer insists on signing the first initial only, he may be allowed to do so, but effort is made to find out what the initial stands for and to note this on the application. The number of suspense cards made out and filed by this company averages approximately 3500 per month, and the average monthly revenue obtained from this file during the past year amounted to \$800, or almost \$10,000 in the course of the year.

Handling Merchandise Sales Orders. Merchandise sales orders are handled as are light and power applications. Many firms are trading on open account with this company, and some accounts must be watched closely, letters being continually written requesting payment on slow accounts, and in a few cases credit being stopped completely pending settlement.

A card file is kept in the department showing customer's name, service location, date signed, the predecessor's name if it is a successor application, the name of the company's agent obtaining the business, and the order number of the contract, which number agrees with the number on the credit slips. Another file is kept which shows all deposits of record, by whom made and for what address, and still another file for line extension advances, which are taken by the credit department and either applied on the light and power account, if the customer is a consumer, or transferred by journal entry to a holding account.

Granting Credit upon House-wiring Contracts. On receipt of a house-wiring contract the name and location are entered

in the receiving book, and a number is given as a means of identification. The location is then looked up through a firm employed for this purpose to see if the applicant's claim of ownership can be verified, the credit data are checked, and references are investigated as in commercial and residence contracts. If the investigation shows the applicant to be a good credit risk, holding title to the premises where the work is to be done, and the relation of the encumbrance to the valuation is not excessive, the contract is approved. If, however, the applicant is found to be buying the premises on contract of recent date and his equity therein is not sufficient to warrant the installation, the holder of title is urged to sign the contract jointly with the applicant. Should the records show the applicant to be buying the property on contract which has extended over a period of years and upon which a substantial sum has been paid, the owner of record is requested to sign a rider giving date of the contract of sale, the amount involved in the contract, the amount the applicant has paid on same to date, and permission to the company to install the wiring, which permission carries the stipulation that all bills are to be paid by the applicant. Contracts of this nature handled by this company average in price, including fixtures, from \$60 up, most of them being around \$200, but occasionally single contracts amount to \$2,000 and more.

Handling Motor and Wiring Order Credits. In taking care of credit matters on orders for motors or for wiring the practice of the company is as follows:

If applicant for motor or wiring is a consumer, both his service and mercantile accounts are scanned and if habit of pay is good the order is approved. If payment is slow or the customer's account would not justify the amount or terms of the order, the customer is so notified and payment in full or in part, as the case may be, is requested in advance.

Should the applicant not be a consumer, his rating, if any, is looked up, his references are investigated, and if found satisfactory the order is passed. If investigation proves otherwise, applicant is notified and advance requested, and a copy of such notice is filed seven days ahead, which if not acted on, is removed from the file and a second or follow-up letter is written, a copy of which is also held seven days, at which time the contract is canceled and returned to the contract department if the applicant's

check is not received. In some cases in the sale of motors, exhaust fans, etc., chattel mortgages are requested to enable the company to recover property should the applicant default in payment.

COLLECTING THE ACCOUNT

There are many ways of collecting accounts. Methods employed by some companies irritate and antagonize customers. Other methods create respect. In some instances collection departments set out with the avowed intention of creating a reputation for harshly handling customers in order that the customers' fear of such handling shall assist in reducing a number of overdue accounts. Some utilities have been known to go so far as intentionally to attract the attention of the delinquent's neighbors to the fact that trouble is ensuing over the payment of a bill. In general, however, this is not the accepted plan among more progressive central stations. Their plan generally is to adopt systematic, thorough and painstaking but withal firm measures of insisting upon payment. It is the endeavor to cultivate the good will of the customer rather than to antagonize him.

Methods of a Middle West Company. As characteristic of these practices the following description of methods employed by the credit manager of a Middle Western electric lighting utility is of interest: This collection system requires the rendering of three statements on all delinquent accounts, namely, the memorandum of arrears, the collector's statement and the "Important" statement. Formerly these statements were printed on addressographs from stencils used for printing the bills and were filled in by long-hand by statement clerks. Recently, however, the department has adopted a very modern system of rendering these statements through the use of four Underwood-type fanfold statement machines. The operation is now so handled that six copies are made in one operation, namely, memorandum of arrears, cashier's stub of memorandum, "Important" statement, cashier's stub of "Important" statement, collector's statement, office copy of collector's statement.

When an account is ten days past due—that is, twenty days after the bill has been rendered—the company sends the customer by mail the memorandum of arrears, in which is printed the following paragraph:

"Please note that bills listed above have not been paid. As same are past due, the favor of your remittance by return mail is requested."

This statement usually brings payment from customers who have misplaced or neglected their bills. To those who pay no attention to it, it is necessary to render the collector's statement. This is sent out ten days after the memorandum of arrears statement was mailed. The collector's statement is made in duplicate, one copy being for the collector and one for the office records. It constitutes the first call statement and is the beginning of the collection department's intimate relations with the customer. If the collector is not successful in securing the money on the first call, he leaves a collector's first notice, which shows the amount due and reads as follows:

"Your attention is called to your past due and unpaid account for electricity amounting to \$____, covering dates for electrical merchandise \$____, electric wiring \$____. Please remit or call at our office and make payment without delay."

Five days later, if no collection has been made, the "Important" statement is mailed. This bears a shut-off notice reading as follows:

"We beg to draw your attention to your past-due account as listed above. We request that this account be paid before the close of business on _____. Otherwise we shall be obliged, with regret, to enforce our rule relative to discontinuing service."

After allowing three days for the customer to make payment the collector makes his second call to collect or discontinue service. He must, however, interview the customer and get his refusal to pay before service is discontinued. In the event that the customer is not at home he will not shut off the service, but will leave a final shut-off notice which reads as follows:

"We beg to advise that, in accordance with notice sent you for your unpaid account for electricity amounting to \$____, call has been made to-day to shut off service. We hope you will render this action unnecessary by paying bill at once at the main office."

The Third and Last Call. This means that the third call must be made if the customer does not remit. On the third call the customer must pay or service will be discontinued. If conditions are such that the collector cannot reach the meter, the case is

turned over to the repair department to collect account or to discontinue service if necessary at the pole. Before this action is taken, however, a letter is addressed to the customer informing him that such action will be taken if the account is not paid. In the event that the service is shut off the collector leaves a slip at the meter showing the amount of the overdue account which was the cause of discontinuing service. Upon the payment of this account the customer can have the service reconnected the same day it is discontinued.

As these various steps are taken memoranda are made on the customer's account at the office so that any inquiry as to the status of his account may be answered.

After service has been discontinued for non-payment the report is held fifteen days, during which time another call is made to collect the account if possible. If the account is not paid, the contract department is informed of the situation and requested to issue an order to have the meter removed.

Dealing with Customers Who Have Moved. The next task of the collection department is to get the money on the final accounts of customers who have moved or whose meters were removed on account of non-payment.

First in order, there is the case of the customer who has moved and is using service at another address. If the balance owed is less than \$1.50, the amount is added to his bill, which will be sent to the new address. If the amount is more than \$1.50, it is given to a collector. If he does not secure the balance, he will leave a notice for the customer. If the customer then does not remit within ten days, another letter is sent requesting payment. Ten days later, if the account has not been paid, a shut-off notice letter is mailed stating that service will be discontinued within three days.

Second, there is the case of the customer owing a final account who gave the company his new address at the time he ordered service discontinued but who is not using service at the new address. The collector calls upon this man and, if he cannot collect the amount, leaves a notice that the balance is due. If payment is not made within ten days, two letters are written at intervals of ten days requesting payment. If remittance is not made then, the collector makes another call. If he is unable then to

collect the amount or to get satisfactory promise of payment, credit data are referred to.

If the correct business address of the customer is shown in the credit data, a call is made at this address and then a letter is sent to the business address stating that the account will be sent to an attorney for payment if it is not settled. After this a few more calls are made by the collector to establish definitely the fact that it is impossible to get the money. Then the account is turned over to the company's attorney with all of the collector's reports, copies of letters, credit data, etc. A card is also filed in the credit department's suspense file to prevent the delinquent from securing further service from the company while his account remains unpaid.

Throughout all of these operations it is the intention of the department to exercise patience and to endeavor to cultivate the good will of the customer and at the same time to establish in the mind of the customer respect for the collection department.

REDUCING THE DELINQUENT ACCOUNT BY 80 PER CENT.

In one year the Muncie (Ind.) Electric Light Company reduced its delinquency account from \$12,591.98 to \$2,225.51, or more than 80 per cent. This was done, says C. L. Walling in the *Bulletin* of the American Gas & Electric Company, the parent organization, first, by creating the office of manager of collec-

Name _____	Folio _____
Address _____	
Amount _____	
Business _____	J. E. No. _____ Date _____
Remarks _____	

FIG. 73—FRONT OF CARD FOR DELINQUENT FILE

tions; second, by insisting upon a deposit with each contract; third, by never closing the books on a bad account, and, fourth, by keeping continually after the old offenders and educating them to pay their bills promptly. The following figures serve to show how well this plan worked out:

	1917	1916
January	\$11,008.94	\$7,444.22
February	10,348.00	9,064.80
March	6,839.73	9,672.39
April	6,703.13	9,461.24
May	5,513.07	10,302.97
June	5,140.99	11,038.65
July	5,123.06	12,278.54
August	5,144.66	10,441.52
September	5,017.13	10,393.71
October	4,510.52	12,350.35
November	4,913.11	15,597.56
December	2,225.51	12,591.98

A file of 3-in. by 5-in. (7.6-cm. by 12.7-cm.) alphabet cards (Fig. 73) is kept of accounts charged off as uncollectible, which

	LIGHT	POWER	MDSE.	CASH
Jan.	_____	_____	_____	_____
Feb.	_____	_____	_____	_____
Mar.	_____	_____	_____	_____
Apr.	_____	_____	_____	_____
May	_____	_____	_____	_____
Jun	_____	_____	_____	_____
July	_____	_____	_____	_____
Aug.	_____	_____	_____	_____
Sept.	_____	_____	_____	_____
Oct.	_____	_____	_____	_____
Nov.	_____	_____	_____	_____
Dec.	_____	_____	_____	_____
Total	_____	_____	_____	_____

FIG. 74—BACK OF CARD FOR DELINQUENT FILE

METER READING, BILLING AND BILLS 235

furnishes quickly the following information: Name, address, amount, ledger folio, business, journal entry number, remarks. The reverse side is ruled so that an itemized account can be quickly entered (Fig. 74).

During the year 1917 the company received many payments which are attributed to this card system. At the last of the month the new-business Ford is borrowed for a few days and a big drive on delinquents is made by the collection department.

Delinquent letters are sent out as soon after the tenth as possible to every delinquent account, and the delinquent list is kept up to the minute.

NINETY PER CENT. COLLECTIONS BY TWENTIETH OF EACH MONTH

Since the increase in postage the Indiana Railways & Light Company has been delivering the monthly bills to its 6000

INDIANA RAILWAYS & LIGHT CO.	
LIGHT AND POWER DEPARTMENT	
Office Hours 7:30 a.m. to 5 p.m.	
Open Saturdays and 10th of Month until 6:00 p.m.	
112 E. Syracuse St.	Nov. 30, 1917
	Phone 231-3885
Present Readings _____	
Last Readings - _____	
K.W.H. Consumed _____	
@ _____ per K.W.H. \$ _____	
Less 1c per K.W.H. on _____ until 10th _____	
Net Bill for November - - - - -	
Less Unread Meter Minimum - - - - -	

Unpaid {	Light {
Appliance {	Balance - - -
Total Amount Due - - - - -	
Save Your Receipts and Delay in Paying Your Bill and Save Your Money and Save Your Energy	
All claims for adjustment must be made by the fifth. All bills payable on or before the tenth. Positively no discounts allowed after that date. We have no collec- tors. Failure to receive bill does not entitle the con- sumer to exemption to this rule.	
November 30, 1917	

FIG. 75—MONTHLY BILL FORM USED BY MIDDLE WEST COMPANY

creditors in Kokomo on the first of the month by meter readers at a cost of approximately \$35 per month, or, roughly, half a cent per bill. Bills are in card form, see Fig. 75, the cards measuring $3\frac{1}{4}$ in. by $5\frac{1}{2}$ in. (8.25 cm. by 14 cm.). The back of the card is used for timely advertisements. A discount of 1 cent per kilowatt-hour is allowed for payment before the tenth, and it is noticed that approximately 80 per cent of accounts take advantage of this. On the twentieth delinquency notices, Fig. 76, are mailed. Only one such notice is sent out by the company to a delinquent.

Collections are as follows: Eighty per cent by tenth of month

Form 21. 2m 12-17


**INDIANA RAILWAYS AND
LIGHT COMPANY**
KOKOMO, INDIANA

Light and Power Department

No. _____ 191

M _____

As the bill presented for electricity
 on _____ 191 ., amounting to
 \$ _____ may have been lost in transit, mislaid or
 perhaps forgotten, we take the liberty of reminding you that the ten-
 day limit will expire _____ 191 , at
 12 o'clock, noon, after which date service will be discontinued without
 further notice.

A charge of \$1.00 is made for re-connecting.

Respectfully,

INDIANA RAILWAYS AND LIGHT CO.

Our customers will save at least one month's lighting bill in the course of a year if they will take ad-
vantage of the discounts given by paying on or before the last day of the discount period.

FIG. 76—DELINQUENCY NOTICE MAILED TO TARDY CUSTOMERS

following period energy was used; additional 10 per cent by twentieth of same month; additional 9 per cent by twentieth of following month—leaving approximately 1 per cent for disconnection delinquents. As will be noticed, a charge is made by the company of \$1.00 for re-connecting service after disconnection or for failure to pay in the proper time.

METHOD USED TO DECREASE DELINQUENT ACCOUNTS

Among the plans which are being developed to assist in hastening customers' collections, those which are based on the reconnection charge idea are said to be most effective. The accompanying form shows how this idea is applied by the Indiana General Service Company of Muncie. With this company all bills are due on the tenth of the month. After the tenth all delinquent

INDIANA GENERAL SERVICE CO.
Date _____

According to our records your account shows a balance of \$_____, which has doubtless escaped your notice. Unless remittance has been made just prior to the receipt of this notice, we ask that you give some urgent attention. If payment in full is not made by noon of _____ we shall, with regret, consider that you desire service discontinued and not necessarily. If service is discontinued, it cannot be resumed until your account is paid in full to date, plus reconnection charge of ONE DOLLAR (\$1.00) and also guarantee deposit is made.

Trusting your prompt attention will render action on our part unnecessary, we are,
Respectfully,
COLLECTION DEPARTMENT.

POLICE _____
M_____

FIG. 77—TYPE OF DELINQUENT NOTICE THAT GETS RESULTS

accounts are taken off the books and notices like that in the illustration (Fig. 77) are sent out. It is this company's policy to give the customer five days from the date of sending these notices to pay his bill. Service is then disconnected without further notice. After negotiations have reached this stage it is necessary for the delinquent customer to come to the office, settle his bill in full, pay \$1 for reconnection and make a deposit to insure payment if he has not already established credit with the company.

Notices of this type were used by the Indiana General Service Company for the first time in July, 1918. As a result Thomas F. English, general manager of the company, stated that a very material reduction was noticed in the number of delinquent accounts.

TRADE ACCEPTANCE HELPS BUSINESS

In the latter part of 1917 the Columbus (Ohio) Railway, Power & Light Company discontinued the sale of electrical appliances and the wiring of old houses on the partial-payment plan.

The matter was considered for a month or six weeks, and at that time it was decided to continue as before, but finally the condition became such that the management issued an order to stop such sales, and this order was immediately put into effect.

As a real new-business department does not enjoy having its means of doing business eliminated, Mr. W. A. Wolls, new-business manager, said before the commercial men of the Ohio Electric Light Association, his department at once set about to find ways and means whereby it could again produce business for the company. Upon investigation it was found that the trade-acceptance plan of financing would meet the requirements. Inasmuch as the company enjoyed the best of co-operation with the electrical jobbers and contractors, a plan for the wiring of old houses was submitted to them whereby the company would give to the contractor a contract to wire a house and on completion of the work would present his bill to the company with a trade acceptance attached ready for the signature of an authorized officer of the company. This trade acceptance would be returned to the contractor. The trade acceptance is made payable in 120 days. The contractor discounts the trade acceptance with his bank at the rate of 6 per cent per annum, whereas formerly the company would discount all bills at 2 per cent for cash. The contractor's revenue for the work done is exactly the same as it was before the use of the trade acceptance. This plan has been in successful operation for the last two months.

In regard to the sale of electrical appliances on the partial-payment plan, the company, Mr. Wolls stated, formerly sold appliances on the basis of 10 per cent down and the balance in ten equal monthly installments. The company has now arranged with the customer a new basis of approximately 25 per cent down and the balance in six equal monthly payments; and with the manufacturers of the larger appliances, such as washing and ironing machines and vacuum cleaners, a basis whereby they accept in payment trade acceptances payable one-third in 60 days, the balance in 90 and 120 days.

Under the foregoing arrangement the wiring of houses and the sale of appliances is done on the basis of 50 per cent, financed by the electrical contractor and the manufacturers of appliances and 50 per cent by the company. This plan, Mr. Wolls states, was a wartime necessity.

**THE DIFFICULTY IN HANDLING APPLIANCE PAY-
MENTS OVERCOME**

Trouble has been found by cashiers of utility companies in taking care of payments on account for special campaigns where these payments were included with the regular bill for meter service. In order to eliminate this difficulty, the Rochester (N. Y.) Railway & Light Company, in one of its special appliance campaigns recently, issued a special colored coupon which is attached to the regular monthly bill of any person who bought one of the appliances in that campaign. When the customer pays his bill for service and also for the appliance the cashier stamps both bills paid in one operation, tears off the special colored slip and places it on a separate file.

SECTION V

COMMERCIAL DEPARTMENT

STOP FLAT-RATE SERVICE TO PREVENT ENERGY WASTE

ON April 1, 1918, the Worcester (Mass.) Electric Light Company discontinued flat-rate service on its system, about 900 customers going over to the metered basis. All of these were residence customers, the commercial flat-rate services to stores and other business establishments having been done away with several months before. Practically no complaint was received from the residence customers, whose monthly bills on the flat-rate plan ranged in general from \$1 to \$3. The company announced the change when it mailed its February bills, each bill carrying a 1½-in. by 5½-in. yellow sticker as reproduced in Fig. 78.

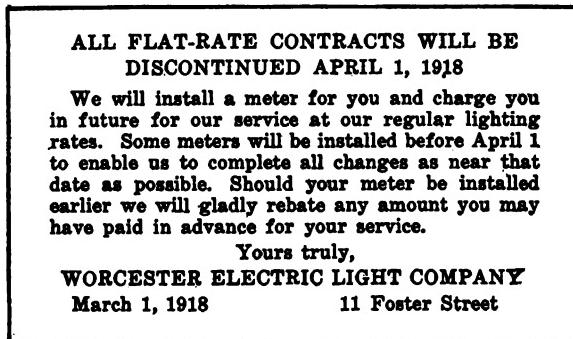


FIG. 78—NOTICE OF DISCONTINUANCE OF FLAT RATE

To the local press representatives officials of the company explained that under the old flat-rate plan considerable energy was being wasted. War conditions demand the elimination of all unnecessary waste, and the anticipated uncertainties of the fuel situation later in the year require the utmost economy in the utilization of electricity. The company also wished to do away with the maintenance of current-limiting equipment used in connec-

tion with flat-rate installations. Then, too, a good deal of time and trouble had been experienced in connection with trips to homes to sign up new contracts for small increases in connected load. The time of year was favorable to the change, with a decreasing consumption of energy for lighting purposes. The flat rates were inaugurated about six years ago, when the company's residential lighting rate was about 12 cents per kilowatt-hour, while the present rate is 8 cents. The flat-rate plan was based on a charge of 1 cent per watt connected per month.

In order to make the change as easily as possible, customers were informed that if a meter should be installed during the months before the first of April customers desiring to go over to metered service then and there would be allowed to do so; but if any one wished to retain his flat-rate service until April 1, the reading of the meter on that date and not on the date of setting would mark the beginning of the new system of charging. In many cases the change to the metered rate was accepted on the spot, the public taking the company's explanation without objection. Data are not in hand at this writing as to the total effect, but it is known that many customers' bills will be no larger under the metered rate than on the flat rate.

FLAT-RATE CUSTOMERS CHANGED TO METER BASIS

Not only must strict economy be practiced to-day in every branch of utility operation but strict attention should be given to average rates for individual services to make sure that the income of the utility is as large as it ought to be. In this class falls the flat-rate customer. W. J. Aicklen, Jr., general manager of the Consumers' Electric Light & Power Company of New Orleans, La., has been checking up the income from flat-rate customers and has found that by changing over to meter service the average revenue for this class of customer can be considerably increased. These flat-rate customers are all connected through load-limiting devices.

A campaign for this class of business was started in the early part of 1913, and through wiring campaigns, etc., about 900 such customers were connected to the company's lines.

In the course of this campaign contracts were made with barber shops, saloons, pressing shops, residences, etc., all at the rate

of 1 cent per connected watt, but after a little experience it was found that this did not pay, when compared with the regular rates. Consequently the rates for places of business were raised from $1\frac{1}{2}$ cents per connected watt for pressing shops to 2 and $2\frac{1}{2}$ cents per watt for saloons.

It was afterward found that even at these increased rates the company was often losing money, when compared with the retail lighting rates. These losses were not only due to the use of energy purchased by the customer for lighting with "mazda" lamps, but were also caused by the temptation that existed for the customer to use an electric fan without the knowledge of the company.

The company has had as many as twenty-five cases where the load limiter was practically destroyed through the customer using an electric iron or a toaster on a limiter with a capacity of only 100 watts. In fact, the average class of customer supplied on the flat-rate basis was found to be rather poor, and it was for this reason that there was so much of a tendency by customers to overstep the terms of their agreement with the company.

On tests made for this class of business, and in different localities, the company found that in a pressing shop paying \$1.50 per month for 100 watts connected 34 kw.-hr. was used, which at the regular meter rate would amount to \$2.24. At a grocery with a load of 200 watts and paying \$2 per month it was found that 45 kw.-hr. was used in a month, which would amount to \$2.90 per month at the regular rate. For a rooming house which was paying \$4 per month for 400 watts connected a consumption of 76 kw.-hr. per month was found, which would amount to \$4.50 per month at the regular retail rate. At another rooming house that was paying \$2.60 per month for 260 watts connected was found a consumption of 49 kw.-hr. per month, which would amount to \$3.10 at the regular rate.

It was such experiences as these that led the company to decide in 1915 that it would discontinue the installation of load-limiting devices for any new customers and that it would replace them with meters wherever there was an opportunity. For instance, if a customer moved from one address to another the company would refuse to move the limiter and would insist on a regular meter being installed. If the customer went out of business and was succeeded by another, the company refused to let the new

customer have the excess indicator, insisting on installing a regular meter. This method reduced the number of load limiters to approximately 500 by the middle of 1918.

"As the load-limiter consumption has always been an uncertain quantity," Mr. Aicklen states, "and as it forms a large factor of uncertainty in the calculation of line losses, distribution losses, etc., the consideration of this, in addition to the facts that we had already learned regarding this class of business, caused us to decide to discontinue entirely all load limiters.

"As all these flat-rate contracts are written up on the yearly basis with a self-renewal clause, it was very easy to reclassify them into twelve monthly divisions, and to notify each division monthly of the expiration of their contracts, which were to be replaced on a meter basis or to be discontinued entirely.

"We have found that we have lost practically no business by this method, and even though we may not have so large a revenue on the meter basis, we will feel better in knowing that we are being paid for every kilowatt-hour sent out, and in creating so much larger a field for the exploitation of electrical appliances, as we have, of course, been restricted from selling any appliance to these flat-rate customers in the past."

SURCHARGE METHOD USEFUL

In several small cities of the Central West served by one company the top step of the rate for electric service was 15 cents. In spite of this apparently high price which the company was getting it was not able to make money enough to pay its operating expenses and was faced with the necessity of shutting down its plant or increasing the price it knew was already high. Realizing that electricity at 20 cents a kilowatt-hour can hardly compete with gasoline or kerosene lighting, the company decided to let its base rate remain at 15 cents per kilowatt-hour and add a surcharge of 5 cents per kilowatt-hour. While this plan in effect increases the rate per kilowatt-hour to 20 cents, it also holds out hope to the customers of the company that the increase is of a temporary nature. The result is that the rate increase has gone into effect and not many customers have asked to have their service discontinued. The manager of the property is certain that if a straight increase in rates to 20 cents per

kilowatt-hour had been made effective, the curtailment of service would have been quite disastrous.

CHANGING A POWER CONTRACT TO OBTAIN GREATER PROFIT

Power for the operation of the Northern Massachusetts Street Railway, serving the Athol-Gardner district of the State, has been furnished by the Athol Gas & Electric Company since 1912. At that time a contract was entered into by which the central station agreed to furnish power measured as direct current at the rate of 1.8 cents per kilowatt-hour and to assume all converting and machine losses. Under the terms of the contract it was necessary for the railway company to build and maintain a three-phase high-tension transmission line from Westminster to the Athol fair grounds, costing about \$36,000. On the basis of an annual consumption of 3,000,000 kw.-hr., the interest charge on this investment amounted to \$1,800 (at 5 per cent) or 0.06 cent per kilowatt-hour, to which was added the interest and depreciation on the company's steam plants, held in reserve, amounting to 0.8 cent per kilowatt-hour, and thus making the total cost of power to the railway company 2.66 cents. A further condition of the contract was that the railway company should maintain the high-tension line in good condition, but little work had to be done on this in the early years of the contract.

Owing to the fact that the load factor was at times much below normal and that the machine loss was large in the substation installation, the central station found itself unable to furnish power under this contract during certain hours at a profit. The railway claimed also that the service did not attain a standard which would enable it to maintain its schedules at all times. In 1916, when the original contract had eleven years more to run, the Northern Massachusetts company and the Athol company entered into a new contract, extending to 1927, upon a basis which would allow a larger profit to the central station and thus give it the incentive to furnish an improved power supply. As the result of this new arrangement the former troubles have been eliminated and the power supply is now continuous and satisfactory to the managers of the railway.

Under the new contract the cost of power to the road (which

has about 31 miles of track), less a discount for payment of bills within fifteen days, is fixed at 1.84 cents per kilowatt-hour, and the energy is measured as alternating current. The railway assumes all converting and machine losses. These amount to at least 20 per cent in the case of this road, or 0.36 cent per kilowatt-hour. Adding interest and depreciation on the cost of the railway company's stand-by steam equipment increases the cost 0.8 cent per kilowatt-hour, making the total cost to the railway 3 cents. The central station took over the transmission line at a cost of \$36,000 in making the new contract. The Athol company purchased part of its energy from the New England Power Company at about 1.1 cents per kilowatt-hour and resold as above outlined.

LIMITATIONS ON FREE SERVICES

In speaking of the war-time practice of the Commonwealth Edison Company in regard to gratuitous service before a recent meeting of the A. I. E. E., D. W. Roper, superintendent of the street department of the company, said :

In the most prosperous times if there was any trouble with a customer's lamps or motors the company would, on request, send its troubleman to the customer's premises. If the interruption to the lamps was caused by some minor defect in the wiring or in the appliances, or the sockets of plugs or switches, the repair man would, if he could do it in half an hour or so, make the repairs sometimes temporarily, but he would make the repairs so as to enable the customer to get service. He would then advise the customer what to do in the way of making permanent repairs. Nowadays the company makes a minimum charge of 35 cents for sending a repair man to the customer's premises. If the trouble is found on the customer's premises and does not have to do with the company's part of the system, the charge is considered valid. In addition, a further charge is made for any time over the first fifteen minutes which the man spends on the customer's premises. This practice applies also to heat-device calls in apartment buildings.

There formerly was a sort of a perpetual guarantee on cords for electric flatirons. The practice now is to charge the customer for the cost of the repair. The charge is 75 cents for replacing an electric-iron cord. This applies also to other heating devices.

Incandescent lamps for a number of years have been delivered free. The company's rates, of course, require that the lamps shall be fur-

nished free, but they do not require that they shall be delivered. It is probable that within the next few weeks the company will make a charge for the delivery of lamps similar to the charge now made in answering a trouble call. It will, of course, be possible, even under the new arrangement, for the customer to get his lamps free by applying for them at one of the numerous delivery stations in the various parts of the city.

FREE RENEWAL OF FUSES DISCONTINUED

The Harrisburg (Pa.) Light & Power Company has recently adopted a new policy in connection with the distribution or renewal fuse plugs. It had been the practice of the company to renew fuse plug burn-outs without charging. This free renewal has been discontinued. Moreover, where it is necessary for the company's troubleman to visit the customer's residence for the purpose of installing fuse plugs, a service charge of 40 cents is made to cover the visit and the installation of one fuse with a charge of 10 cents for each additional fuse installed. Fuses called for at the office by consumers are now sold for 10 cents each, instead of 5 cents, as before.

This innovation has had an immediate effect in reducing the number of trouble calls for fuse installation, while the revenue derived from the necessary calls which are still being made, and paid for, is taking care of the troubleman's time and putting him on a self-supporting basis. Special pains are being taken to instruct the consumers how to install fuse plugs in order that they may take care of their own burn-outs, and it is believed that it will not be long before most Harrisburg householders will provide themselves with extra fuses so as to be prepared to take care of any trouble which may develop. There will then be no call on the utility to send a man when it is simply a case of unscrewing a burned-out fuse and putting in a new one.

REDUCTION OF LAMP RENEWALS RESULTS

The Houston (Tex.) Lighting & Power Company last fall inaugurated a campaign of education for the purpose of reducing the annual burden of lamp renewal expense and has been so successful that already a very large saving has been effected. Of course the Houston public has read as much about the "mazda"

lamp as the people of any other city, but the company had been granting free renewals on "gem" lamps and a large number of consumers had continued to burn these lamps.

The great popular interest in coal conservation and other war-time savings, however, suggested the possibility of a special campaign for "mazda" lamps that would call attention to the wastefulness of the less efficient incandescent lamps and secure the general adoption of "mazda" lamps.

H. O. Clarke, commercial manager, in commenting on the campaign, says:

The policy of free lamp renewals carried out by a great number of large central stations is to-day merely the inheritance of a mistaken and misguided policy of the past, and in the central-station game a precedent once set and established becomes a rule which it is hard to change, especially so in the furnishing of free renewals. A great many people believe that the abolishment of a practice which gives them something free is simply an effort on the part of the central station to make for itself additional money and to take from the customer a service to which he is entitled. Selling the idea to the public of the advantage of purchasing a high-grade lamp rather than accepting free an inferior lamp is really the basis of a campaign to reduce lamp renewals. To aid us in driving home the thought we have hit upon the plan here in Houston of using a counter display rack, which consists of two compartments, in one of which is placed a "mazda" lamp and in the other a free-renewal lamp or exchange lamp. The two compartments are connected separately, each to a meter, and the meter dials are calibrated to read in dollars and cents.

When a customer comes into our office the first thing we do is to take him to this display box and show exactly why we can afford to give away an exchange lamp. At the same time we show him a comparison of the color values of the lamps, and we follow this with war-time arguments, appealing to the patriotism of the customer on the basis of fuel conservation. The dials assist us in showing that the fuel consumption necessary to serve the "gem" lamp is twice that required to serve an equivalent candle-power of "mazda" lamp.

The work has been very effective, and we expect that we shall be able to reduce our free lamp renewals to the value of \$400 for the entire year. We do not expect to have to furnish a single free lamp in 1919. When one stops to consider that in the short period of time since "mazda" lamps came in we have been able to reduce our free lamp renewals from \$7,000 to \$400 per year—and in 1919 we hope to reduce them to nothing per year—it will be agreed that our educational work

along this line has been most effective. Last year our total cost was \$1,646.40.

We have not done any advertising in this campaign, nor have we announced any policy of abolishment of free lamp renewals, and our results are attributed solely to untiring personal efforts in educating and appealing to the patriotic sense of the customer.

DISCONTINUE LAMP SERVICE

On July 1, 1918, New York Edison Company and United Electric Light & Power Company, supplying New York City and the Bronx, discontinued the practice of furnishing incandescent lamps under the lamp-service contract which includes the furnishing of the first installation and subsequent renewals of 50-watt lamps and larger at a monthly charge of $\frac{1}{2}$ cent per kilo-

<u>LAMP ORDER</u>	
DATE	191
THE UNITED ELECTRIC LIGHT & POWER CO. 130 EAST 18TH STREET, NEW YORK	
PLEASE DELIVER	{ CLEAR 50 WATT STANDARD CENTRAL FROSTED STATION MAZDA LAMPS
OTHER SIZES _____ AS PER PUBLISHED PRICES. FOR USE ON PREMISES NOTED BELOW.	
BEST TIME TO CALL NAME _____ ADDRESS _____	

FIG. 79—FORM OF LAMP ORDER FOR CUSTOMERS' USE ADOPTED BY THE NEW YORK EDISON COMPANY

watt-hour consumed. From now on the two companies will supply lamps to customers only at the standard list prices, but in supplying these lamps will maintain an adequate delivery service in addition to counter service. Moreover, facilities were afforded to customers so desiring to purchase their initial equipment of lamps on a deferred-payment plan, full payment to be made in six equal monthly installments to be added to the lighting bill.

There were several reasons for discontinuing the lamp-service arrangement other than excessive cost. First, the service was not altogether satisfactory to the consumer, owing largely it was felt to the inability of a consumer thoroughly to understand the

arrangement; second, it was somewhat unfair to the consumers using heating and other appliances to be charged for lamp service on the basis of the entire energy used when a considerable portion of that energy was used for other than lighting; and third, the addition of 10 per cent at the first of the year to the standard price of lamps was a greatly added burden to the companies, which distributed annually in the neighborhood of \$1,000,000 worth of lamps and which would have required considerable advance in the lamp-service contract. Even an advance to 1 cent a kilowatt-hour would not have taken care of all of the additional charges, it is understood, and therefore the service has been discontinued.

The companies have standardized on the 50-watt lamp and by making it easier for the customer to purchase 50-watt lamps than other lamps hope to maintain the average lighting wattage.

Customers have been furnished with return post cards on which they may place their order. One of these is here shown, and as will be noted, by using this card it is much easier to purchase the 50-watt lamp than any other size. In notifying the customers of this change, a circular was sent out which gave also the prices at which lamps would be sold. A 10 per cent discount is allowed to purchasers of standard package quantities.

The company has taken the stand that it will not permit customers to receive discounts on yearly purchase of lamps for deliveries at specified intervals throughout the year. Discounts will be given only on purchases as made. In this way the company relinquishes a considerable amount of business to the local dealer in lamps.

NO FREE RENEWALS FOR SMASHED LAMP BULBS

The Edison Electric Illuminating Company of Boston, which has been very liberal in regard to broken and lost lamps, has found that present-day conditions have made certain economies necessary, among them being a change in lamp policy outlined in a notice sent to customers which stated that on and after Feb. 15, 1918, a charge would be made for lamps replaced where the glass is broken. This does not change the renewal service furnished by the company, but places the burden of careless and excessive breakage on the customer.

The handling of broken lamps under the new rule has been in effect now for more than two months with remarkable success, the company states, and is operating with notable smoothness. The customers seem to appreciate that property furnished for their use by the company must be properly handled and receive due care in order to prevent its unnecessary destruction.

STOPS FREE DELIVERY OF LAMPS

The Commonwealth Edison Company of Chicago, which includes free lamp renewal as a part of its service, stopped gratuitous distribution of the lamps January, 1918. At customers' requests lamps were formerly delivered free of charge anywhere in the city. Under the present arrangement when a customer calls at the lamp service bureau the clerk states that the company has, for the convenience of its customers, established lamp service stations in various parts of the city and gives the person who calls the address of the nearest station. The customer is also told that there is a complete stock of lamps at this station and that an attendant there will help him select the proper sizes of lamps. For those who do not wish to call at the stations for lamps the company still maintains a delivery service, for which it charges 35 cents per call.

The lamp renewal stations, of which the company now has twelve, usually occupy space in stores that are already established. This number of stations will probably need to be increased. In selecting these stores it was suggested that real-estate agencies might be desirable concerns to carry the lamps since they have to maintain stores and have nothing in the way of stock to occupy their windows. On reconsideration, however, it was decided that the most desirable locations for the lamp renewal stores were places of business which had something to gain by having electric service customers call for lamps. The twelve agencies are located as follows: One printer's store, one electric fixture store, one building formerly vacant, three hardware stores, two drug stores and four buildings already partly occupied by the company. This arrangement gives one store to each zone of $2\frac{1}{2}$ miles to 3 miles (4 km. to 4.8 km.) in the city.

An analysis of 1000 calls for lamps made just after the new system was installed showed that about 10 per cent of the custom-

ers would rather pay the 35 cents charge than call for lamps in person. This ratio is expected to decrease, however, as familiarity with the system increases.

FIXTURES FORMERLY RENTED NOW SOLD OUTRIGHT

A few years ago the commercial department of the New Orleans (La.) Railway & Light Company instituted a practice of installing high candlepower "mazda" fixtures on a rental basis, the object being to discontinue arc-lamp service. In all about 1500 of these lighting fixtures, or "pendants," as they were called, were put out, and up to within a few months ago the monthly rental produced a very satisfactory revenue over the operating expense. The influence of the war, however, has upset these conditions and increased the cost of maintenance until it practically balances the revenue. It has been decided therefore to discontinue the rental of "mazda" fixtures, but to continue the furnishing of them on a straight sale basis.

Customers were called upon to purchase outright the fixtures then in use on a rental basis, and this turnover brought in a considerable amount of money and a large margin of profit. Some of the fixtures had been in service for several years, though they were in perfect condition, and the price on the present basis of cost was well in advance of the original cost thereof. There was very little difficulty experienced in taking care of this change-over, for the fixtures were giving entire satisfaction, and it was by far more expensive for the customer to give them up and purchase something else.

A CHARGE FOR RECONNECTION FAVORED

Among central stations of the Middle West there is a growing tendency to enforce more strictly rules concerning a charge for reconnecting a customer's service when it has been disconnected for non-payment or other causes. The general policy seems to be to make a charge of \$1 for this reconnection. There are some managers, however, who favor increasing this amount to \$2. Strict enforcement of this rule is said to do much to cut down unnecessary labor charges incident to disconnecting in order to collect money and reconnecting after payment has been made.

A firm policy on this matter has the further advantage of making collections easier and payments more prompt. This latter feature is considered important under prevailing financial conditions.

Among those who favor the two-dollar charge are some who have many customers that ask for disconnection during the summer months while they are away from their city residences. It is figured that if the company has its investment in lines, transformers and meters for these customers idle during the summer months, more than a reconnection charge of \$1 should be made for the periodic discontinuance of service.

SIZE OF WATT-HOUR METER

According to a discussion on meters at the recent convention of the Minnesota Electrical Association, there is a very decided tendency toward the installation of meters of smaller sizes. Where there is any question about the size of meter to install some central-station companies are using small-size meters, leaving it to the new-business department to obtain as large a load as it can. This practice has led to practically no trouble. In Minneapolis 95 per cent of the meters installed are of the 5-amp. type. Even for electric ranges, meters of the 15-amp. variety are used there. It is never desirable to install a meter of higher rating than is necessary to register the load efficiently and economically. Putting in too large a meter not only increases the investment in meters but also results in a large loss of revenue owing to light-load inaccuracy.

In general, when installing a meter the class of service must be considered. What applies to one customer does not necessarily apply to another. For example, in churches, stores, lodge halls, saloons, etc., the total connected load is nearly always used and a meter rated at 80 per cent of that load should be installed. For electric signs and like loads meters rated for the total connected load should be installed. In residences only a few lamps are used at one time, as a general rule, and they are usually not of large size. Occasionally during some special functions the total connected load will be used. At such times a small meter would have to carry considerable overload. However, most of the modern meters will carry 200 to 300 per cent overload with-

out danger of damage to the meter and will carry 400 per cent for a few minutes. The meter will operate slow on overload owing to the fact that the series-coil laminations are oversaturated. However, the infrequent loss resulting from overload will be compensated for by the increased activity of the meter on small loads of one or two lamps. Hence it is always advisable to install a meter having a rating equal to 25 per cent to 50 per cent of the total load in a residence.

The same rule also applies to power customers having many small motors or one large motor. It is always advisable to install a meter with 60 per cent to 75 per cent of the rating of small individual drives and 75 per cent to 100 per cent for a large single motor. Experience has proved that this is the best practice except with motors operating elevators and cranes which are started and stopped frequently. These motors draw large starting current, so the best practice is to use a meter with 100 per cent to 125 per cent of the rating of the connected load.

CARD CONTRACT COVERING LIGHT AND POWER SERVICE

A simple form of card contract (Fig. 80) is used by the Southern Canada Power Company, Ltd., Montreal, Que. The card measures 8 in. by 5 in., and on the reverse side it has the same contract except that it is in the French language, because of the large French population.

<i>Application for Service</i>	
Name.....	
No.	Address..... Date.
To The SOUTHERN CANADA POWER Co. Limited	
Operating.....	
Please connect the premises at..... to your ELECTRIC LIGHTING service subject to your rules and regulations as adopted from time to time for which service I agree to pay monthly at your Office at the following Rate.....	
Subject to a minimum monthly payment of..... dollars (\$.....)	
Meter rent..... per month. Subject to a discount for prompt payment of % if paid within discount period.	
This agreement to be effective for one year from above date and to continue in effect thereafter until notice in writing of 30 days shall be given for the disconnection of the service.	
<i>Witness</i>	<i>Applicant</i>
<i>The foregoing is signed by the applicant after reading and receiving a copy of same, and is subject to the Company's acceptance by letter addressed to consumer within thirty days. Acceptance may also be made by making connection at the point of delivery.</i>	
Received from the sum of dollars (\$.....) or letter of security No. as guarantee for the fulfillment of above application and guarantee to be returned when the service covered by this application is discontinued.	
Householder? <input checked="" type="checkbox"/>	 To be returned when service is discontinued.

FIG. 80—CARD CONTRACT USED BY MONTREAL COMPANY

The average contract used by light and power companies is crowded with numerous regulations legally phrased and which not infrequently serve to frighten the prospective customer, especially if he be a householder. In addition, as has frequently been shown, such contracts do not lend themselves readily to convenient filing. With this Canadian company the regulations are kept on file and are available whenever required, while the card, satisfying all practical purposes, is filed with others of its kind.

The card when filed constitutes an option on the customer's business for a period of thirty days. Besides, it acts as a deposit form. A copy is retained by the customer.

APPLIANCE SALES COMMISSION FUND FOR THE SALESPeOPLE

To give an added impulse to appliance sales in 1918, the Potomac Electric Power Company of Washington, D. C., placed aside a 5 per cent commission on everything sold out of the electric shop which is paid into a monthly fund and distributed to the members of the sales department. This distribution is made by equal division; that is, if the profit for the month is \$250 and there are ten salesmen on the staff, each one receives a check for \$25. It is found that this is aiding materially in the development of an organization spirit because of which the men are co-operating eagerly and "tipping each other off" to opportunities discovered outside the discoverer's own territory.

INSTALLMENT PERIOD ON RANGE CUT

The plan under which the Pacific Gas & Electric Company of San Francisco formerly sold electric ranges called for 10 per cent cash and the remainder in twelve monthly payments. The company paid the installation cost, which was figured to amount to \$50, and this amount was allowed on all ranges installed on the company's lines whether sold by the company or by outside agencies. If the customer desired to pay cash for the range, a discount of 10 per cent was allowed.

Since the power situation in California has grown acute through the increase in the price of oil, abnormally low stored water supply and rapidly increasing demand for power, the

range policy has been revised so that it will no longer be a burden to the commercial department. The present plan is to sell at manufacturers' list less \$20 per range, which is deducted as an allowance on cost of connection; the average installation cost is about \$50, or \$60 including water heater. The terms of payment are 25 per cent cash and the remainder in three monthly payments. If the customer desires to pay cash, a 5 per cent discount is allowed. The connection allowance of \$20 is made only if the range is sold by the company.

The rates remain the same as before (averaging slightly less than 4 cents per kilowatt-hour), and the same service to consumers will be continued. Under the new plan the cost to the consumer will be greater, but it is hoped that the electric range department will be self-sustaining.

PEAK-LOAD RELIEF

Equalization of the peak loads of customers in order that existing station capacity can be utilized more fully is of unusual importance at the present time. At the 1918 N. E. L. A. convention at Atlantic City, N. J., R. R. Young presented a paper telling how this plan was worked out and of the results obtained by the Public Service Electric Company of New Jersey.

The territory of this company in so far as generation and distribution is concerned is divided into two zones, designated as northern and southern zones, the southern zone comprising Trenton, Burlington and Camden with adjacent territory, the north-

RESULTS OF CAMPAIGN TO EQUALIZE CUSTOMERS' PEAK LOAD

Division	Total Kw.		Promised		Actual Relief Obtained	
	Connected Load in Power	Promised Kw. Relief	Per- centage Relief	Kw.	Percentage	
Essex	73,000	4,360	5.9	.....	....
Hudson	40,000	5,245	13.1	.....	....
Passaic	20,000	1,852	9.2	.....	....
Central	41,500	3,909	9.4	.....	....
Bergen	8,700	1,050	10.8	.....	....
 Total	 184,200	 16,416	 8.9	 10,000	 5.4	
Southern Zone..	23,900	2,931	12.2	1,500	6.3	
 Grand total	 208,100	 19,347	 9.3	 11,500	 5.5	

ern zone comprising all north of and including New Brunswick and its adjacent territory.

Late in the summer of 1917 the company found that it would be unable to start a 35,000-kw. turbine and a 12,500-kw. turbine which were under erection in two of the largest generating stations. It was decided, therefore, that, beginning with November,

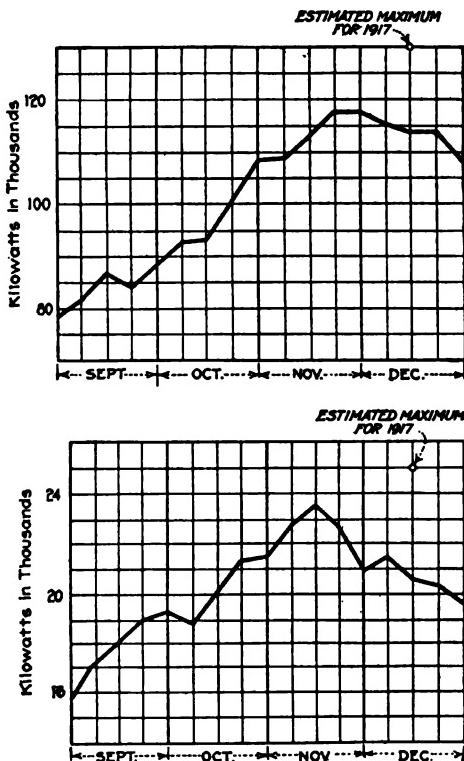


FIG. 81—PEAK-LOAD DISTRIBUTION OF NEW JERSEY ELECTRIC COMPANY;
NORTHERN ZONE ABOVE, SOUTHERN ZONE BELOW

a systematic canvass of power customers should be made, asking the co-operation of the manufacturers using 50 hp. and more in redistributing their load throughout the day so that heavy demands which ordinarily might occur between the hours of 4.30 p. m. and 9 p. m. would be changed to some other hour during the twenty-four-hour day.

Blueprints showing a typical twenty-four-hour composite load curve of the generating stations for December, 1916, were pre-

REPORT ON REDUCTION OF PEAK

Customer .....	.....
Business .....	.....
Address .....	.....
Town .....	.....
Substation from which customer is fed.....	.....
Connected load	hp.....kw.
Maximum demand .....	.....kw.
Demand 4 to 9 p.m.....	.....kw.
Promised relief at peak.....	.....kw.
Remarks:	.....
Interviewed by:	.....
Signed:	.....

pared for the power representatives and agents, and a mock interview was held to illustrate the methods to be used in presenting the case to the manufacturers.

After the company's organization had been thoroughly prepared, the men began about Nov. 1 to visit the power customers, the campaign continuing throughout the month of November. Report forms were prepared (Fig. 82) and results of calls on individual customers were reported daily, these reports being tabulated by the general office. Weekly meetings of the power representatives in the state were held to discuss difficulties encountered and methods of overcoming objections.

Inasmuch as the rate schedule includes no off-peak provisions, the only advantage the manufacturer was to derive was the possible reduction of his average demand, thus reducing his demand charge somewhat, besides giving him greater insurance against interruptions in service.

The result of this campaign in promises from the customers is shown in the table.

Owing to the fact that customers were probably not able fully to live up to their promises, and there being some diversity in the peak loads, it is estimated that the result of the off-peak canvass was the securing of approximately 10,000 kw. reduction in demand in the northern zone and 1500 kw. reduction in de-

REPORT ON REDUCTION OF PEAK	
Customer	
Business	
Address	
Town	
Substation from which customer is fed.....	
.....	
Connected load	hp.....kw.
Maximum demand	kw
Demand 4 to 9 p.m.....	kw
Promised relief at peak.....	kw.
Remarks:	
Interviewed by:	
.....	
Signed:	
.....	

FIG. 82—REPORT FORMS FOR CALLS ON CUSTOMERS

mand in the southern zone. In fact, the maximum peak occurred in the last week in November in the northern zone, whereas, the peak of former years had been occurring in December.

Kilowatt-hours sold during November and December indicated that no curtailment of use resulted from reduction of peak. In other words, the maximum capacity required was reduced by 11,500 kw. without reduction in output on the part of the manufacturer.

The daylight-saving law as now effective will not help the fall peak. If the period is extended to cover the entire year, the saving in necessary capacity by the central station will be considerable.

FINANCING NEW TIE LINES

Under present conditions, with coal at a high level of prices and with winter-time deliveries of fuel very uncertain, many a company operating a small steam plant naturally feels that it would like to tie in with a neighboring large transmission company if possible. By so doing it not only shifts the generating responsibility to another company which may have some water power, but it also may reduce somewhat its production cost and put off into the far future any possibility of expenditures for plant replacements. From the small plant's viewpoint interconnection at the present time has many advantages.

When the tentative proposal to the transmission company is made, however, the difficulty of financing the tie line between the present transmission system and the small steam plant looms large. The large company is having trouble taking care of the financing of necessary war business and its own community. The transmission company would be glad to furnish the service at 2.5 cents to 3 cents per kilowatt-hour, however, if the financial difficulty were not in the way.

In the Northwest a number of companies are getting around their troubles in a common-sense sort of way. The small company with the steam plant is financing the line and in turn is selling it to the transmission company, taking in payment the stock of the transmission company. This plan works well for several reasons. First, the small company can easily raise the money for the line in its own little community because its present security holders and the other investors in its town are in businesses that are not greatly affected by war. They are accustomed to putting their income in banks or putting it back into their local business and are willing to divert it to a local utility enterprise at a fair price. So the small company can raise the money. Second, it appears a good stroke of business to take the large company's stock in payment for the line because they get it at a price to yield around 8 per cent and are likely to come out handsomely on any advance in market value. This method is satisfactory to the large company particularly because it relieves it from the financial strain. It is usual practice for the small company to draw the specifications for the line it expects to build and then submit them to the engineers of the larger company for

such revision as may be thought necessary to make them conform fairly well with the transmission company's standards of construction. The small company then does the actual building of the line. This has been found wise under present circumstances, for the small company can usually build the line at a great deal lower cost than the transmission company. At first it may seem paradoxical that the small company with less experience can build cheaper than a large concern with transmission specialists. It is true nevertheless. The difference in cost comes largely in the labor-camp and transportation expense. The small company can pick up labor in its own easy market and usually makes no special provision for housing and feeding the men. They know the community and shift for themselves. Farmers with teams do the hauling during lulls in farm work, and this keeps down transportation expense.

This plan of providing service has, therefore, many advantages to both companies. It is being used to the mutual advantage of concerns in the Middle West and Northwest and is at the same time making for increased capacity in the small towns and for conservation of the nation's fuel.

METHODS OF FINANCING EXTENSIONS OF LINES

Before a recent meeting of the commercial men of the Indiana Electric Light Association, R. Thurman of Muncie presented a comprehensive digest of plans used by various utility companies in the Central West for financing extensions under the present conditions.

Owing to the high cost of materials and labor and to the fact that utilities probably will not be allowed to capitalize at this high figure, only absolutely essential additions will be made, Mr. Thurman pointed out. As to what is considered essential, this will vary with each utility and with every case presented. However, there are in most cases different ways of taking care of lighting and power customers. A brief summary of a few of the different systems follows.

In the standards of electrical service established by the Public Service Commission of Indiana, dated Jan. 2, 1918, Rule 31 provides that each utility shall, upon request for service, make free of charge any line extension necessary to give this service, when

the income for the first year from the prospective customer is equal to one-half the direct cost of the extension. If the cost of the extension is greater than the estimated income for the year, the customer is required to deposit the cost of the extension above the free limit. If other customers are taken on this extension, the original consumer is to receive a rebate of an amount equivalent to the cost of the free extension for each customer so taken.

A number of companies are using this rule with reference to both light and power, particularly lighting consumers. In figuring the cost of the extension, the majority of utilities include the cost of material, cost of labor, including meter and meter installation, and to this add 10 per cent to cover cost of engineering and superintendence.

The Pacific Light & Power Company of Portland, Ore., uses the same method as given in Rule 31 (see *Electrical World*, Feb. 9, 1918, page 311).

Some companies are requiring the total amount of the cost of extension to be advanced by the consumer, especially the power consumers. This is returned to the customer in energy, in some cases the total amount of the bill being applied each month, in other cases from 25 per cent to 60 per cent of the bill. Other companies use a plan in which the total cost is advanced and an amount equivalent to the 1914 cost is returned in service. This applies in the majority of cases to large extensions for additional power consumers. This seems to the author to be a very good method of taking care of high-cost extensions, owing to the fact that it is probable the utility will not be allowed to capitalize the full amount expended on these extensions.

One company at the present time is asking that the total cost be advanced and promises to return nothing. This applies only to lighting consumers. In this connection the question of how an extension made in this way can be capitalized arises. Another plan is to set a limit for cost and then to ask the customer to pay any additional expenditures. This plan applies particularly to lighting consumers, and the amount set as a limit to be spent for each lighting customer varies from \$20 to \$50. The consumer is required to deposit in most cases any additional amount, which is returned to him in energy. Under the terms of still another system the prospective consumer is required to purchase preferred stock to the amount of the cost of the exten-

sion. In most cases this preferred stock pays a dividend of 6 per cent, which really amounts to borrowing the money from the consumer at that rate. This seems to the author to be one of the very best methods of taking care of extensions at the present time, owing to the fact that it not only secures the necessary capital but also gives the customer an interest in the company.

In securing data for this paper a circular letter was sent to each of the central-station members of the Indiana Electric Light Association asking for information regarding their method of taking care of extensions. Answers from seventeen central stations were received, which are classified as follows:

FOR LIGHTING CUSTOMERS:

No extensions being made	5
No advance required	5
Extensions made according to commission Rule 31	3
Total amount advanced by customer, nothing returned.....	1
Customer required to buy preferred stock equivalent to cost of extension	1

FOR POWER EXTENSIONS:

No extensions being made	5
No advance required	4
Advance required, but total amount returned in energy.....	5
Customers required to buy preferred stock equivalent to cost of extension	1

A number of the replies from central-station companies, especially the smaller ones, revealed the fact that they were having trouble with their customers in securing necessary cash to finance extensions. In some cases this had assumed such proportions that it was necessary absolutely to call off plans for extensions of any kind, on account of prospective customers refusing to advance the money by any of the above methods. This, however, the author believed is because the applicants for service had not been educated up to a point where they understood that it was impossible at this time for a utility company to make an investment in any other way.

FINANCING THE FARMERS' LINE

Running north from Berrien Springs, Mich., through a rather thickly settled farming community, is a newly built 9-mile (14-km.) extension to the system of the Indiana & Michigan Electric Company of South Bend, Ind. The line serves farmers

only. It operates at 4400 volts, single-phase, and is constructed of 30-ft. (9-m.) wooden poles spaced on 150-ft. (45.7-m.) centers and carrying No. 6 copper wire. The line cost \$11,800 and reaches 120 customers. To finance the line each farmer gave the company his promissory note for \$102 before construction was started, with the understanding that the entire amount should be refunded in electrical energy at the rate of \$1.50 per month. In all the company collected from the farmers \$12,240, which it will have returned at this rate in about five and one-half years.

The average customer on this line has a ten-room house, each room of which is wired for electric light. The average cost of wiring and fixtures complete, ready to turn on the energy, was \$70 for a ten-room house. The average connected load in a ten-room house on this line is 600 watts. In connection with this lighting load there will be more than fifty motors of 1 hp. or less, which will be used for pumping purposes. In such cases where the motor rating does not exceed 1 hp. in capacity it is attached to the regular lighting meter and adds nothing to the monthly minimum charge. There will also be a number of motor connections for units of larger capacity than 1 hp., and in such cases the motor will be put on 220 volts and a service charge of \$1 per horsepower per month will be added to the energy charge. Practically every farmer along the line has signified his intention of wiring his barn and garage, so the total lighting load will soon amount to about 700 watts per customer exclusive of the motors. The 120 customers will be served from thirty-five transformers, in some instances as many as five customers being served from one transformer. It is interesting in this connection to know that where a farmer has a tenant house on his farm he can make connection to this building without extra cost to him except the cost of wiring the building.

The lighting rates charged on this installation are 11 cents per kilowatt-hour, with 1 cent discount, making 10 cents net with a \$1.50 minimum charge per month. The average income for rural lines for residential lighting is approximately \$150 per month, making an income on this line of approximately \$2,160. When all appliances and stoves are on, as they will be within one year, the gross income will be approximately \$3,500, which is approximately 30 per cent of the cost of the line. This, it is figured, will give the company the income it requires on the line.

These rates and this financing plan do not include any provision for the long drop necessary to reach some farmhouses far back from the road. In the construction of the line the company allowed 300 ft. (91 m.) for each service connection. In case the customer's house was more than 300 ft. from the line, he was required to pay for all additional construction at the rate of \$25 per 150-ft. span. The amount paid for this additional construction is considered as payment for a private line which is owned by the customer but maintained by the company.

The company's viewpoint on the situation, as explained by M. F. Caldwell, manager of the new-business department, is given in the following paragraphs:

"In serving the farmer life is made more pleasant for him, since electricity lessens his desire to go to the city in order that he may enjoy the city's luxuries. If the central station can meet these demands of the farmer, more food will be raised, and it takes food as well as bullets to win the war. Moreover, after the war there is likely to be a period of readjustment in some of the country's industries that will cause a reduction in demand by some of the central station's power customers. With the farmer it is hardly expected that there will be such a period. The line which is built now will be paid for while the farmer is receiving top price for his goods and while it is easy to sell him electric service. Therefore, why not meet his demands now while he has the money and is willing to spend it? If he does not spend it for these improvements, he will spend it for something else which will perhaps do him less good, and the central station will lose an opportunity to get his business and to keep him satisfied on his farm raising food for the nation.

"In cases where a careful survey shows that the line would give insufficient revenue to pay a reasonable profit on the investment, the company believes that sufficient of the farmer's deposit should be retained to reduce the investment to a figure which the revenue from the line will justify."

CUSTOMERS TO PAY EXCESS OVER 1914 COST

A new system of service charges has been adopted by the Alliance (Ohio) Gas & Power Company, effective Nov. 1, for residences and commercial loads of 5-kw. rating and less. This

applies in any instance where the company is required to make an expenditure (1) for the installation or construction of additional or specific overhead lines on streets, alleys, highways, rear lot and side lot lines, including poles when necessary, and usual equipment, wire, lightning arresters, line switches, ground wires or connections, or for any work on existing poles with all of the attendant equipment for increasing the existing distribution system or transmitting direct to the applicant's premises; (2) for transformers wherever installed, excepting only standard service transformers, and (3) for construction on applicants' premises exclusive of overhead service loops, meter and any overhead or underground construction on rear or side lot lines as already described.

The applicant is required to deposit with the company an amount equal to the estimated cost of the work done upon the understanding that the work constructed shall remain the property of the company. However, a refund to the amount of the estimated cost of this work, except construction on applicants' premises, as of July, 1914 (called normal cost), will be made to the depositor at the rate of \$20 for each customer's installation connected to this work within ten years. This refund shall not exceed the amount of the normal cost and shall not be payable unless written notice is given by the applicant to the company of the consumers' installations connected to this work. No interest is allowed on the amount deposited. Furthermore, the company has the right to refund at any time all or any part of the unrefunded portion of the normal cost of the work.

Moreover, each additional customer on this line connected within ten years of original contract date shall pay one-tenth of the cost of this construction above the normal cost at the time of filing his application for service, which amount shall be refunded to the original depositor until nine-tenths of this abnormal cost shall have been refunded, when such collections from applicants and refunds to depositors shall cease.

The Alliance company is a Doherty property, and it was stated that other Doherty properties in Ohio would probably follow this method, which has received the approval of the Ohio Public Utilities Commission.

FIXED PRICE ON SHORT EXTENSIONS

The problem of line extensions during war times has in most instances been solved where long extensions were to be made. Short extensions, merely connecting a service on existing line, also require capital, and the expense involved may easily run into a good many hundreds of dollars in a short time. The Elmira (N. Y.) Water, Light & Railroad Company has found a way of obtaining the required money by applying a customer-financing method to even the small extensions.

Each prospective customer is approached frankly and told of the conditions faced by the utility in war times and of the necessity for having financial assistance wherever extensions are required. It is pointed out that utilities must refrain from issuing securities at the present time unless authorized to make an issue and that consequently funds are not available for line extensions. It is further shown that the increased costs of labor, materials, fuel, etc., have reduced the net income to such an extent that financial assistance must be had from prospective customers.

However, the customer does not pay for the line but only lends the necessary money at 6 per cent for such time as the company needs it. The company guarantees to recall all of the outstanding certificates that it has issued and refund the total amount of the money that has been advanced with interest added. Care has been taken to impress upon all customers this fact that they are not buying or paying for the service, but are merely assisting the company in financing the purchase of the necessary material and labor. The company does not refuse to run any extensions, but points out to the customer that unless financial assistance is rendered the company will not be able to make the extension until some other way has been found to finance the proposition.

Where it is necessary to extend the wires a distance of 300 ft. to 500 ft. the company first finds out from the line department what the cost of these extensions will be. On ordinary service, however, where the secondaries run right up to the house the company has been asking the consumer to advance \$11. This has been found to be about the average cost of service during the months of June and July. Prior to that time the cost was a trifle less, the increase being due to the gradual advance in the cost of material and labor.

Should a prospective customer point out that it is impossible for him to advance the cost of the extension, he is then asked to go to the bank and borrow the money, and this has been done in some instances.

The Elmira company was wiring about 100 houses a month during 1918, and in each instance the customer was asked to

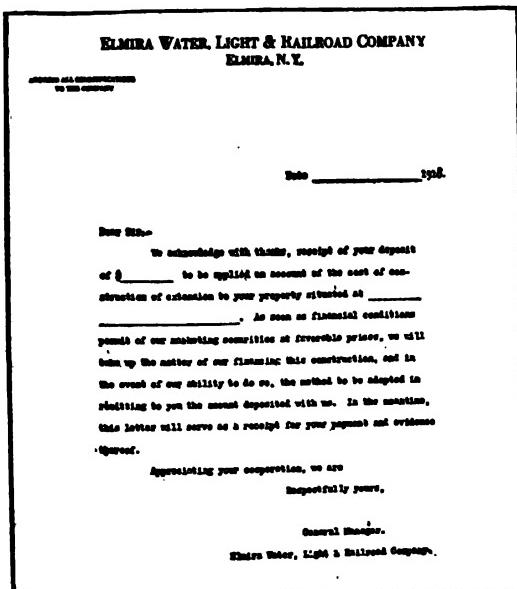


FIG. 83—CERTIFICATE OF RECEIPT FOR MONEY ADVANCED BY CUSTOMER

assist in the service construction. Almost always he has advanced the money.

It was also found necessary to impress upon all employees the necessity for taking this step so that they can speak intelligently on the subject to any one. In addition, each of the electrical contractors in the city and surrounding counties has been notified what the company is doing so that no consumer will have his house wired without being absolutely familiar with the conditions of connection to the company's mains or secondaries.

SERVICE-CHARGE FOR POWER LOADS

A new customer's charge for commercial loads in excess of 5 kw. capacity has been drawn up by the Alliance (Ohio) Gas &

Power Company, effective Nov. 1. This applies in any instance where the company is required to make an expenditure (1) for the installation or construction of switching apparatus, for additional or specific switchgear, meters, instruments, panels, frames, control, cables and buses, connections and transformers, in switch houses or substations; (2) for additional or specific overhead lines, including poles or towers, with necessary and usual equipment, wire, lightning arresters, line switches, ground wires or connections, or for any work on existing poles or towers, with all the attendant equipment for increasing the distribution system or transmitting direct to the consumers' premises; (3) for any transformers installed in switch houses, substations, line houses or other structures not otherwise specified, and (4) for service on customers' premises, for the installation of poles, power lines, ducts, cables, and also where the transformer capacity to be installed exceeds 50 kw. for the transformers and switching required and for special transformers of 50 kw. rating or less.

The company contracts to supply a given amount of kilowatt line capacity to the premises in question, and this capacity the company agrees to hold and reserve for use of the applicant ten years from the commencing of supply, subject to federal, state, county, township or municipal regulation.

How the Refund Is Worked Out. A deposit of the estimated cost of the work upon the understanding that the work shall be the property of the company is required. A refund will be made of the estimated cost of this work as of July 1, 1914 (called the normal cost), (A) on the energy used by the applicant and taken from the line constructed as specified, and (B) in addition on the energy taken and used by other consumers connected to the lines so constructed, except where the work constructed consists of feeders or an addition to the network, in the general distribution system of the company, in which event refund to the applicant will be made only on the energy used by those consumers who are connected to that part of the work specifically constructed for the applicant which extends beyond the network of the general distribution system of the company. Provision is made, however, that in no case shall the amount refunded to the applicant on the energy used by any consumer exceed the normal cost of that portion of the work constructed

which is useful in serving that customer. That amount refunded to the applicant should be based upon the energy taken and used within ten years after commencement of supply, and the total amount of the refund should not exceed the normal cost of the work applied for.

Moreover, the refund will be computed at a rate per unit as determined by the following formula: Refund rate per kilowatt-hour = dollars \div (36,000 \times contracted kilowatt demand). The sum of the money in this formula is the normal cost of the work as described. The refund will be paid by the company to the applicant annually. The kilowatt demand in this formula is the capacity contracted for and reserved to the use of the applicant by the company.

No refund or interest shall be paid unless the applicant's bills for energy have been paid in full, nor shall any annual refund payment exceed 50 per cent of the sum of the bill for the energy used within the refund period from the work of construction under the application. Besides, the company reserves the right to refund at any time all or any part of the unrefunded portion of the normal cost of the specified work. No refund of interest whatsoever will be allowed on the excess cost of the specified work, which excess is the difference between the normal cost and the amount deposited.

Interest not exceeding 6 per cent per annum will be paid by the company to the applicant annually upon the balance of the normal cost held at the time and subject to be refunded, and this annual rate of interest will be computed by this formula: Rate = 0.6 of 1 per cent \times average hours' use per day of the contracted kilowatt demand.

The hours' use per day of the contracted kilowatt demand in this formula is to be determined by dividing the monthly average of kilowatt-hours upon which refund is allowed by thirty times the demand contracted for.

PAYING DEMAND-METER INSTALLATION EXPENSE

When a Middle Western central station began to install demand meters on its larger industrial customers' installations it found quite frequently that services were taken into the premises from two or more widely separate points. To rearrange the

wiring so that the total instantaneous demand could be measured on a single meter meant a considerable expenditure. The company did not feel that it could afford to go to the expense of making the change. At the same time it realized how much to the benefit of the customer it would be if the change were made. To induce the customer to pay for the change in this wiring, therefore, was the problem.

In most cases the difficulty was cleared up by measuring the demands on the separate services and presenting a bill based on the total of the separate readings, together with an explanation of the reduction which could be made if the owner would change his wiring so that the demand could be measured at a single point to give him the advantage of his load diversity.

SECTION VI

MANAGEMENT

SELLING STOCK LOCALLY

A STOCK-SELLING campaign in its home territory just completed by the Dayton (Ohio) Power & Light Company was somewhat unusual in that it was handled by the company's own men exclusively. The major portion of the work was carried by the commercial department under the direction of Thomas F. Kelly,

An Investment Opportunity In One of Your Public Utility Properties

An opportunity is now available to our customers to become financially interested in this large public utility system—
to share in the moderate returns following efficient, progressive and economical management and full consideration for the rights of the public.

The Dayton Power & Light Company is now operating in Montgomery, Greene, Clark, Clinton and Miami counties and

supplying electric service to forty-one communities including the cities of Dayton, Piqua, Xenia and Wilmington. In addition we supply Steam Service in Dayton, Heating Service in Piqua and own and operate the Waterworks system of Wilmington.

We desire to encourage increasing proprietorship in the company by all customers. There are at present more than 1500 widely-scattered stockholders.

Among the many reasons commanding the purchase of the 6% Cumulative Preferred Stock of the Dayton Power & Light Company now are the following:

We will sell a \$100.00 share for \$65.00 in cash or in monthly payments and you will earn 7% on your investment.

Each share can be purchased by paying \$10.00 down and the balance in five payments of \$15.00 each.

Business and gross earnings have steadily and substantially increased since organization in 1911.

This stock has paid quarterly dividends of 6% per annum regularly since the organization of the company.

The company is a large organization with annual gross earnings in excess of \$2,000,000 and with properties located in diversified communities.

The company publishes an annual report which is accompanied by certificate of audit by an independent auditor.

Dividends on three or more shares will return to you enough to pay the average residential light bill for a year.

Your capital and the money it bears for you will remain at home.

FROM ONE TO TWENTY SHARES MAY BE PURCHASED FOR CASH OR MONTHLY PAYMENTS. THE SMALL STOCKHOLDER IS WEL-COME AND PURCHASERS OF ONE SHARE WILL RECEIVE THE SAME CONSIDERATION AS THE PURCHASER OF THE MAXIMUM NUMBER. DETAILED INFORMATION UPON REQUEST.

'It's a mighty good buy'

The Dayton Power & Light Co.
50 South Jefferson Street

Bell, Main 4494

Horne 6166

FIG. 84—INTERESTING THE LOCAL PUBLIC IN UTILITY STOCK

commercial manager. The issue consisted of 560 shares of \$100 par value authorized for sale by the Ohio Public Utilities Commission at \$85 per share. The plan was to sell not more than twenty shares or less than one share to any person. At the end of three weeks 387 shares had been sold, and the whole amount in less than five weeks. The issue, being small, was sold without any really intensive sales effort. Some newspaper advertising in

THE DAYTON POWER & LIGHT COMPANY
Home Telephone Building, 50 South Jefferson Street
DAYTON, OHIO

July 15, 1918.

TO OUR CUSTOMERS:

The Public Utilities Commission of Ohio has authorized a limited issue of the company's 6 per cent cumulative preferred stock, the proceeds of which are to be used for additions to our property.

We have felt that a large number of our customers would be glad to avail themselves of an opportunity to invest their savings and thus become partners and part owners in this local enterprise, and therefore, for the first time, we are offering our stock to our customers under the following arrangements:

Each customer will be permitted to buy from one to twenty shares of this preferred stock at \$85 per share (par value \$100 each). Payments may be made in cash or on the following installment plan:

Ten dollars a share to be paid at the time of subscription and fifteen dollars a share per month to be paid at the time the bill for electric service is due, until the full amount of the subscription has been paid, which shall include the accrued dividend from the last preceding dividend date.

Interest at 5 per cent per annum will be allowed on all payments until the final payment is made, when the investment will begin to earn 6 per cent.

The purchase of this stock at \$85 a share means that you will earn over 7 per cent on the money invested, and in addition this stock is tax-free in Ohio.

Your subscription will be received at our office or our representative will call at your convenience. Dividends on three or four shares will return to you each year enough to pay the average residential light bill for a year. The fullest investigation of this offering is desired.

Yours very truly,

THE DAYTON POWER & LIGHT COMPANY,
THOMAS F. KELLY, Commercial Manager.

FIG. 85—A LETTER TO THE CENTRAL STATION'S CUSTOMERS

Dayton and in other towns served by the company was used. The advertisement reprinted herewith is typical (Fig. 84), the slogan in the literature being "It's a mighty good buy." As further producers of inquiries personal letters (Fig. 85) were employed, and local bankers in the smaller towns were personally told of the issue in order that they might suggest it to prospective investors asking advice. An interesting feature of the publicity campaign was that the first stock purchaser was the printer who was employed to get out the literature. Proofreading the copy convinced him that he should voluntarily subscribe to the issue to the full amount of his savings.

SELLING PREFERRED STOCK AT HOME

Under present financial conditions in the principal money markets of the country, the difficulty of securing funds is becoming a more serious matter every day to the utilities. One plan, however, that seems to produce results even when money is particularly tight is that of selling securities to the public in home territory.

Within the past three years a number of companies have tried out this scheme for raising funds, and in every instance, so far as records show, they have been more successful than was anticipated in the beginning. For a number of months the Pacific Power & Light Company of Portland, Ore., has carried on an active campaign for selling its preferred stock. The principal reason for this campaign, the company states, is to secure a greater distribution of stock among residents of the territories it serves and its employees. It says:

The interest of our customers and the employees of the company is mutual. Our growth and welfare is closely interwoven with the advancement of each and every one of the communities we serve. Each customer who is a stockholder, we believe, will take a more active interest in our company, and it is this interest that every large company wants and must have to be a success.

For a given amount of stock, a large number of holders are desired in preference to a few large stockholders. The importance of making this campaign is great. Every employee, whether in the office, a lineman, a meterman or a power-department man, we hope will do all within his power to do his part in actually selling the stock.

COAL CHARGE BRINGS HIGHER UNIT REVENUE

An instance of increased unit revenue resulting from the application of a coal charge is afforded by a street railway's transactions with a central station situated on tidewater in eastern New England. The power contract between the two concerns is based upon a price of coal not exceeding on an average \$4 per ton delivered at the wharf. Should the average price be in excess of \$4 per ton, then the railway company pays the power company at the end of each year an amount equal to that obtained by multiplying such excess per gross ton by the number of gross tons of coal actually burned in generating electricity for the railway company. The amount of coal so burned is taken as bearing the same proportion to the total coal burned in the station as the electrical energy used by the railway company, as measured, bears to the total energy generated in the station and distribution from it. This contract was made when the price of coal was about \$3.37 per ton, so that the power company was obliged to stand the loss between \$3.37 and \$4 per ton before any adjustment was made. For the year 1917 the cost of power to the railway company was \$223,593, an increase of about \$55,000 over the amount paid in the year ended June 30, 1916. The average price of coal for 1917 was \$7.51 per ton against \$3.65 for 1916. The average price of coal for 1917 was \$7.51 per ton against \$3.65 for 1916.

The unit selling price of energy to the railway by the central station at the alternating-current terminals of the railway substations was 1.77 cents for the year 1917 per kilowatt-hour, compared with a base price of 1.4 cents per kilowatt-hour made for coal at \$4 per ton. In 1917 the central station received 0.37 cent more per kilowatt-hour of alternating-current energy delivered at the substation terminals than in 1916. The total energy generated at the plant in 1916 cost 0.42 cent per kilowatt-hour for fuel and 0.84 cent in 1917, or an increase of 0.42 cent. As the cost of generation per kilowatt-hour delivered at the substations as alternating-current energy exceeds the cost of production per kilowatt-hour at the plant itself on account of the reduced number of kilowatt-hours delivered at the substations compared with the energy produced at the main plant, it is apparent that the additional price paid by the railway in this case did not fully

compensate for the increased cost of coal at the main plant. The central-station company bore part of the added burden, and in support of this practice it is contended that if a company shares a part of the burden of increased costs it will find its applications for rate advances more favorably regarded by the public and by the public utility commissioners having jurisdiction over it in rate matters.

HOW INCREASED RATES AFFECT REVENUE

Tabulating the results of rate increases in utilities of several hundred communities has made it evident that increasing rates in some classes of utility service gives the full measure of expected relief, while in other classes of service the increased revenue actually derived is not so great as the extent of the rate increase would indicate that it should be. When the need for rate increases in utility business became apparent commercial men began to speculate as to the probable effect. It was remembered that on the occasion of each decrease in rates it had been possible by intensified sales effort so to increase the volume of business as to keep the company's revenues from falling off markedly because of the lower schedule. Moreover, the constant tendency was for patrons enjoying a rate decrease to use more service, so that the actual money paid for service remained about the same after the decrease as before it. Reasoning conversely on this proposition, in anticipation of the coming necessity for increasing rates, it would seem that a curtailment in the use of energy might be expected to follow. This, of course, was taken to mean that rate increases of, say, 15 per cent would not produce a 15 per cent increase in utility revenue.

In some measure this line of reasoning was correct, but with the gas utilities it was totally incorrect. It appears to be almost universally true that a given percentage of increase in gas rates will produce the same and in some cases even a greater percentage of increased revenue. Utility managers believe this is attributable to the difficult fuel situation. Customers, instead of curtailing gas consumption on account of increasing prices, have been forced to use more gas because it was more available and perhaps cheaper than coal or oil.

Electric utilities have not enjoyed the same experience. As an

average figure it may be said that a given percentage of increase in electric service rates will produce an increase in revenue equal to only 75 per cent of that indicated by the rate advance. In other words, a 20 per cent increase in rates increases the revenue only 15 per cent. Not only do patrons cut down on the use of energy when the rates go up, but there are other external factors that must be taken into consideration, including the daylight-saving measure and the curtailment of service for classes of lighting not sanctioned by the Fuel Administration.

UTILIZING SURPLUS CAPACITY OF WATER-WORKS STATION

The enormous demand for power upon central-station companies has presented a problem to operators which it is becoming increasingly difficult satisfactorily to meet. A number of contracts have been entered into between central stations and large industries manufacturing their own electrical energy for use by central stations of every kilowatt over and above the needs of the industry concerned.

Another interesting phase of the situation, which will possibly be a partial solution of the difficulties of some central stations, has now come to light through arrangements being made by the utility companies for the purchase of energy from municipalities operating their own waterworks systems. A contract of this nature lately entered into in a Middle Western city of the 25,000 population class calls for the purchase of the entire output of electrical energy generated by a 225-kva. generator over and above the pumping requirements.

Under the terms of the contract the waterworks bind themselves to furnish such electrical energy at all times, and the company to receive and pay for such energy to the extent of its demands for a period of three years; and provision is made that if during the term of the contract the waterworks shall have any additional electrical energy for sale the company shall have the option to purchase it at the same rate and under the same terms as provided in the contract for the purchase of the energy generated by the 225-kva. generator.

The rate provided to be paid by the company to the waterworks for the electricity so purchased is somewhat in excess of the

actual cost of generation by the company's own generators, but the advantage of having an immediately available supply of electrical energy for war-time demands outweighs this small difference.

Provisions are made, of course, for the accurate measurement of energy received by the company under the contract and for rebating pro rata to the party suffering from any inaccuracy discovered. The contract further provides that during the life of the contract the company shall not be required to pay the waterworks for electrical energy purchased so long as the city is indebted to the company for street-lighting service, and that in the event of the city paying the company for its street-lighting service in scrip or warrants the waterworks will accept such scrip or warrants at full face value in payment for electrical energy purchased by the company from the waterworks.

The contract for the purchase of this energy was made conjointly with the renewal of the street-lighting contract existing between the city and the company. It provides the waterworks with a means of disposing of excess electrical energy generated at a profit and gives the company a reserve supply of power which it so much needs.

ECONOMY OF GOOD POWER FACTOR

The cost of transmission lines is greatly increased by low power factor. For example, the number of pounds of copper required on a transmission system operating at 70 per cent power factor, writes Will Brown, Electric Machinery Company, Minneapolis, Minn., is at least 33 per cent more than is required if the system

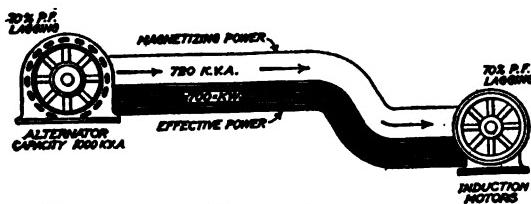


FIG. 86—MORE USELESS THAN USEFUL CURRENT CIRCULATES WITH 70 PER CENT POWER FACTOR

As a result larger conductors and switching equipment are required, the apparatus supplying energy must be larger, and maintenance of constant voltage is more difficult.

operates at 90 per cent power factor; but very often the nearest standard-size wire (or gage) may considerably exceed the exact requirements (in circular mills). Thus the percentage of cost may be largely increased, in some cases to the extent of 60 per cent. That is, if the system at 90 per cent power factor requires 100,000 lb. (43,360 kg.) of copper, the system at 70 per cent power factor requires 159,000 lb. (72,120 kg.) of copper, it being understood that both are 60-cycle systems with the same line drops, operating at full capacity and carrying the same rated kw. load.

One can go further into this matter of waste caused by low power factor by considering the two systems compared below, each having 3000 kw. in motors. System A operates at a power factor of 90 per cent lagging (3333 kva.), whereas system B operates at a power factor of 70 per cent lagging (4285 kv.). Both deliver the same power, viz., 3000 kw. The initial costs of the two systems are as follows:

	System A	System B
Generators ¹	\$34,200	\$44,100
Transmission lines	45,000	72,000
Transforming and switching equipment..	7,000	9,250
Motors, etc.	35,400	35,400
 Total	 \$121,600	 \$160,750

Nearly \$40,000 worth of additional equipment must be installed to enable system B to operate at 70 per cent power factor and still carry the same kw. load as system A at 90 per cent; and this is by no means all the waste involved, for there is a constant loss due to greater heating caused by the low power factor.

The proper use of synchronous motors—that is, for the type of duty for which they are adapted—will go a long way toward relieving conditions of low power factor. Synchronous motors for power-factor correction should be installed as near as possible to the causes of lagging power factor. The reactive current then circulates between the induction motors and the synchronous motors only, and the generators and distributing lines are relieved thereof.

There is another way of looking at the value of improving power factor which should be particularly interesting at this time, namely that larger loads can be carried without increasing

¹ Prime movers not included.

the generating, transforming or distribution facilities if the power factor is raised. This may afford the quickest way of providing for increased production since it does not involve the purchase, delivery or installation of a large amount of equipment.

As an example of what can be done along this line attention may be called to one plant which was operating at an average power factor of 72 per cent lagging and which was driving about 1400 hp. of induction motors of various sizes ranging from 1 hp. to 200 hp. It became absolutely necessary that a large motor be added to the line for driving a compressor. The alternators were already loaded to the safe overload capacity. A 500-kva.

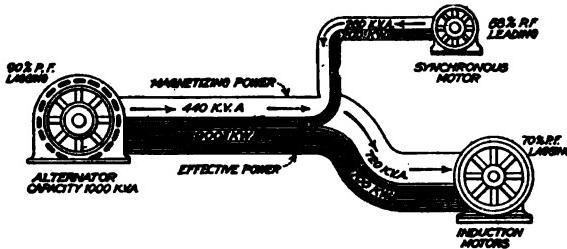


FIG. 86A—MIXING SYNCHRONOUS APPARATUS WITH INDUCTION MOTORS REDUCES USELESS CIRCULATING CURRENT

The synchronous equipment can also carry load and permits using smaller conductors, switches, etc., or at least allows using the reserve capacity for other purposes. Reserve capacity is also released in the energy-supply apparatus.

Synchronous motor was added to the system to drive the compressor (about 280 hp.). By overexciting the motor so it would run at a power factor of 42 per cent leading it was possible to raise the power factor of the system to approximately 90 per cent. The same alternators are now driving the original 1400 hp. of motors plus the 280 hp. used for the compressor and are actually generating less kva. than before. Under the new conditions it requires only 1400 kva. at 90 per cent power factor to serve nearly 300 hp. more equipment than under the former condition when the alternators were delivering 1460 kva. at 72 per cent power factor. (See Fig. 87.)

The reason why the induction motors are so much too large for their work is primarily found in the fact that the motor voltage is 550, which is an unusual voltage for induction motors, so that

it was difficult to find in stock the right size motor for each purpose. The buyers picked up motors where they could find them, often taking a 50-hp. motor where one of 25 hp. would have been sufficient for the load.

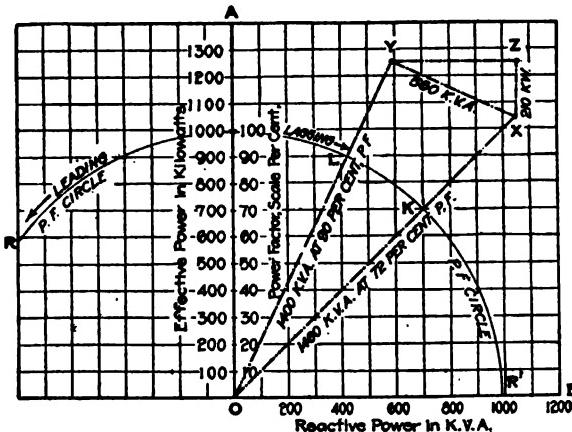


FIG. 87—VECTOR DIAGRAM SHOWING EFFECT OF RAISING POWER FACTOR FROM 72 PER CENT TO 90 PER CENT BY SYNCHRONOUS MOTOR

The synchronous motor rated at 500 kva. is delivering 210 kw. of mechanical power at the same time that it is correcting the power factor of the system. The original system was delivering 1460 kva., of which only 1050 kw. was employed usefully for mechanical power. After the addition of the synchronous motor the system delivered 1260 kw. of mechanical power, while the apparent kva. was reduced from 1460 to 1400. By similar diagram any one can figure the size of the synchronous condensers required to produce the desired power factor on his lines. It can be seen by the diagram that it rarely pays to raise the power factor above 90 per cent as the amount of condenser capacity required is very large in proportion to the increase of effective kw. which can be secured.

From an engineering viewpoint it is much better to buy a motor just large enough for its average load, and if in the future it should be necessary to drive a heavier load, the old motor can be replaced with one of larger rating. Much money can be saved by such practice in the first cost of the motor, the higher efficiencies secured, and from the standpoint of generating and delivering power.

Rubber factories as a rule suffer from poor power factor, caused by many large induction motors running at part loads. A certain rubber company obtains a rate from the central station based on a maximum demand of approximately 8000 kw.

at a power factor of 90 per cent. Should this power factor drop to 70 per cent, the rubber company is penalized at the rate of \$1 per kilowatt per year on the maximum demand for that month. In order to maintain power factor at 90 per cent the company has installed two condenser sets with a rating of 2000 kva. each.

When to Use a Synchronous Motor. Wherever a large, constant-speed load is to be driven the very first question asked should be: "Can a synchronous motor be used to drive this load?" If starting and running conditions are such that this is possible, the question ought to be answered in favor of the synchronous motor. The matter should be viewed both from the standpoint of motor efficiency and also from the broader viewpoint of overhead cost for delivering power. Following is a typical case as outlined by a prominent central-station manager.

A centrifugal pump requiring 400 hp. and with a speed of approximately 600 r.p.m was to be driven by an alternating-current motor. There were to be a number of other smaller motors at this plant. If a 400-hp. induction motor was installed, it was estimated that the average power factor of the load would be 70 per cent lagging. The average power factor of the load with a 400-hp. synchronous motor driving the pump would be over 90 per cent power factor. The comparative efficiency of the two motors was considerably in favor of the synchronous unit.

The following table shows that nearly \$14,000 more initial investment¹ would have been required of the central-station company to serve the load if the 400-hp. induction motor had been installed than was necessary with the synchronous motor installed:

Transformer substation	\$430.00
2300-volt service	215.00
13,000-volt distributing system	1,806.00
Step-down substation (50,000 volts to 13,200 volts)....	774.00
Transmission lines, 50,000 volts	8,600.00
Step-up transformers, 13,200 volts to 50,000 volts.....	774.00
Generators	1,290.00
 Total	 \$13,889.00

On a basis of 10 per cent for interest and depreciation this would mean an annual charge of \$1,389 against the induction motor when compared with the synchronous motor.

¹ Based on total kilovolt-amperes required with both arrangements.

Under the conditions the central-station company absolutely refused to furnish power for this load unless a synchronous motor was used.

Changes are rapidly being made in regard to power-factor regulation.

One large manufacturing company near Chicago which is a large user of power received a bonus for one month of more than \$1,300 as a result of maintaining a power factor better than 95 per cent. In contrast to this, a rather small company using power was penalized \$1,900 last year for low power factor. It is interesting to note that this concern was operating a motor-generator set consisting of a 150-hp. induction motor driving a direct-current generator. Owing to the fact that the maximum load of the generator was never more than 40 kw. or 50 kw. and generally much less than this, the power factor on this induction motor was very poor. If this had been a synchronous motor of similar rating operated at its full kva. capacity, the power factor of the interior system would have been so raised that there would have been no penalty imposed. Thus in one year's time a saving of \$1,900 would have been effected, or more than enough to pay for the motor.

One of the large power companies in Ohio has the following clause in its contract:

When the current supply is alternating and the greater part of the load is power and the billing demand exceeds 75 kw., the company reserves the right to test the power factor of the consumer's load, and if the average power factor is greater than 75 per cent, then the demand shall be reduced in accordance with the following formula: Billing demand = kilowatt demand as measured \div average per cent power factor \times 75.

If the average power factor is less than 60 per cent, then the demand shall be increased in accordance with the following formula: Billing demand = kilowatt demand as measured \div average per cent power factor \times 60.

The company will make without charge a power-factor test at the consumer's request once a year, if his demand exceeds 75 kw. By power factor is meant the average power factor under normal operating conditions.

A number of companies in Illinois operating under the Illinois Public Utilities Commission incorporate the following clause in power contracts:

"Should the power factor fall below 80 per cent, the energy as metered shall, for billing purposes, be subject to an increase in the ratio of 80 per cent to the actual power factor as used."

The following clause is quoted from an Indiana company's contract:

"The primary charges will be increased by 1 per cent for each 1 per cent the power factor on the entire load decreases below 75 per cent at any time."

AUTO-TRANSFORMER BETTERS POWER FACTOR

After the installation of more efficient lamps on a series street lighting system, a central station in New York State found that the power factor was very materially lowered, owing to the lower voltage at which the transformers were required to operate. This was due to the fact that the desired illumination could be secured with the more efficient lamps of the old current rating

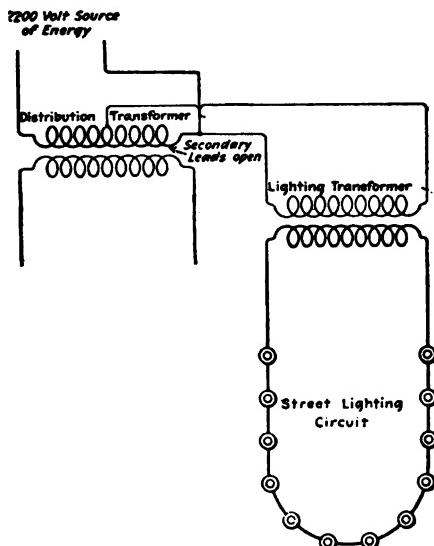


FIG. 88—HOW AUTO-TRANSFORMER MAY HELP POWER FACTOR

with lower voltage units. To improve conditions a distribution transformer was connected across the source of supply as shown in the accompanying diagram, Fig. 88. Its primary acted as an auto-transformer and its secondary was open. The primary was

tapped midway between the two terminals, 1100 volts being impressed upon the terminals of the lighting transformer. This greatly increased the power factor of the system and obviated the purchase of an additional step-up transformer of correct size. Of course, this connection was facilitated by the fact that the distribution transformer had 50 per cent taps on the primary.

IDLE GENERATOR IMPROVES POWER FACTOR

It is not unusual to connect a synchronous machine to some part of a circuit to improve the power factor, but a company in New England has found a method of doing this which utilizes any generators which may be idle. This is made possible by the fact that it has duplicate transmission lines running from its main generating station, only one of which is ordinarily required to carry the load. The other circuit is provided for emergency use and also to take care of future increases in load. When the power factor gets low the duplicate lines are paralleled at their distant ends, and any generator that may not be carrying load is connected to the reserve line. It is then allowed to run as a synchronous motor, being excited enough to compensate for the low power factor at the delivery end of the line.

A slight load can be put on the generator if necessary to secure the desired wattless current by allowing some water to flow through the waterwheel.

This arrangement, besides utilizing equipment that would otherwise be idle, improves the power factor in both the line and the generators carrying load, whereas if it was merely floated on the bus as a synchronous condenser it would not benefit the line. By so doing it is also possible during a sleet storm to circulate enough current through the reserve line to melt any sleet which may adhere to the conductors.

CORRECTING POWER FACTOR IN DISTRIBUTION CIRCUIT

To take on an additional load of 160 hp. in a 550-volt secondary network system, where the primary feeder, switchboard panel and transformers were operating at over capacity, 570 kva., at a power factor averaging 60 per cent and at times running as low

as 50 per cent, was the problem which confronted the engineers of Lynn (Mass.) Gas & Electric Company about three years ago, according to J. F. Dubois, manager of the electric department. The company was supplying energy to the neighborhood containing the factory by a 550-volt secondary network, shown in Fig. 89 in single-line diagram, banks of transformers being connected in at various points.

Two courses appeared open—first, to improve the power factor of the operating circuit, and second, to install a new circuit with the necessary transformers, etc. The matter was discussed with engineers of the General Electric Company, who suggested that static condensers might be utilized, although no equipment of this kind for outdoor work had been developed at that time. It appeared that if the second plan of dividing the existing network and installing the necessary transformer and three-conductor cable from the station, together with switchboard panel and instruments, was followed, the operating conditions would not be improved, but that existing troubles would be increased. The generators would still be supplying the cables and transformers, with the transmission of a large wattless current. On the other hand, by the use of the static condenser the overload on the cables

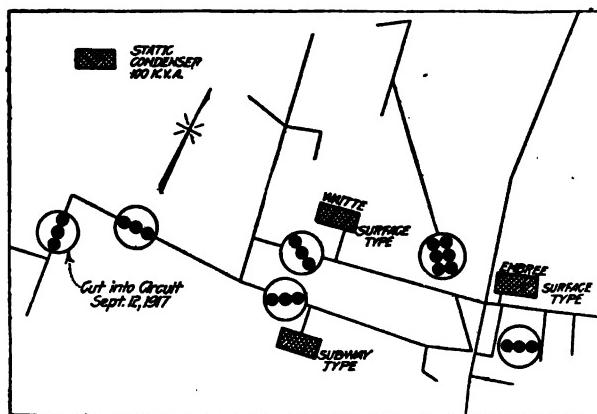


FIG. 89—LOCATION OF TRANSFORMER BANKS AND CONDENSERS

would be reduced. Generator and transformer capacity would be released for other service and the power factor would be improved along the whole system back to the generator. No ex-

citation or operating labor would be required for this form of apparatus.

Early in 1915 two static condensers rated at 100 kva. each were installed and connected to the secondary network. Space not being available at the factory first mentioned, one unit of

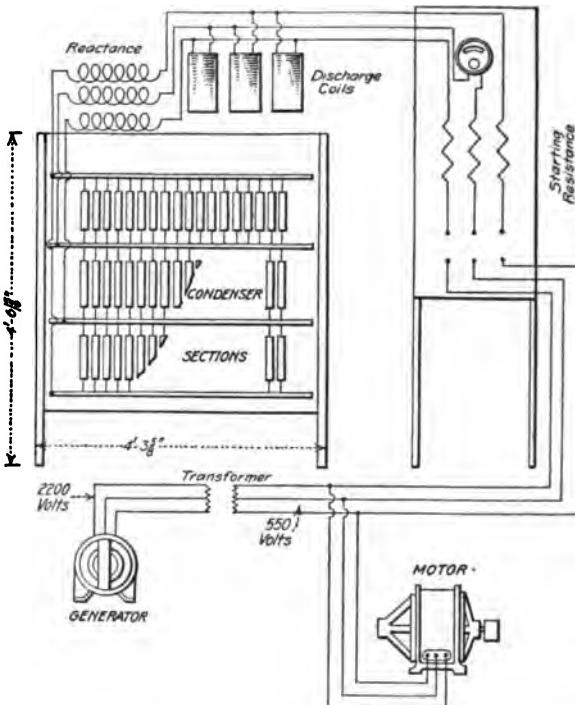


FIG. 90—ARRANGEMENT OF STATIC CONDENSER EQUIPMENT STATIONS

100 kva. was located in a machine shop across the street. At another point, between banks of transformers shown in the circles in Fig. 89, a portable galvanized-iron building was erected to house the other condenser. The company found itself able to take on this factory of 160 hp. in motors without the addition of a single transformer or the changing of the circuit in any way except in the installation of the condensers. The power factor of the circuit at the station was raised to about 78 per cent.

The results from this were so satisfactory that in the past year another unit, of the subway type, was installed in an or-

dinary transformer manhole on Munroe Street, Lynn. In this case the cells are inclosed in two tanks, the accompanying reactance being inclosed in a smaller tank about the size of a 5-kva. transformer. An oil switch and contactor are inclosed in another tank, and an ammeter with transfer phase switch and push-button control are placed in a pedestal on the sidewalk. This equipment is working perfectly at present and in a recent test it raised the power factor of the circuit at the station from 60 per cent with the condensers all off to 90 per cent with all the units in, the present load being about 440 kva.

IMPROVING POWER FACTOR AND VOLTAGE REGULATION

Since early in the summer of 1917, writes J. T. Peyton, of Westinghouse Electric & Manufacturing Company, the Duquesne Light Company, serving the Pittsburgh district and the counties of Allegheny and Beaver in the southwestern part of Pennsylvania, has had in operation on its lines a 7500-kva., 11,000-volt, 600-r.p.m. synchronous condenser for raising the power factor of the system and maintaining voltage regulation. After this condenser was put in service and its ability to handle the unfavorable conditions imposed on the Rankin plant was successfully demonstrated, the Duquesne Light Company ordered two duplicate machines. One of these was installed during April at the Beaver Falls substation, 32 miles (51.5 km.) from the Brunot's Island plant, and connected by two 66,000-volt transmission lines, each having a capacity of 20,000 kva. This station is at the end of the 66,000-volt system, and the load at that point at the present time is only about 500 kva., so the condenser for the present will be used for controlling the voltage, some method of regulation being necessary on account of the line impedance and the comparatively high reactance of the transformers now in use. The other one, when completed, will be placed in the Lawrenceville substation, where the conditions are somewhat similar. As the company expands and the load on the system increases, it will very likely continue to place synchronous condensers at the principal load centers, and the time may come when it can obtain practically a flat voltage curve notwithstanding variations in the power factor.

Benefits of Synchronous Condensers. There is nothing new

in the application of synchronous condensers to this class of service, for there are many of them in operation to-day and have been for years. However, when one stops to consider that many of the companies are operating close to maximum rating during these war times, and that generating equipment is necessarily at a premium with a large number of them, it is rather surprising that these machines are not in greater demand. In all probability there are many cases to-day where the conditions are such that the introduction of a condenser would solve the problem, or at least go a long way toward the solution. With the unprecedented increase in prices of apparatus and materials of all kinds, the vital consideration, of course, is the expense incident to any change involving new equipment or construction work. However, a little analysis on the part of the operator who is pressed for sufficient capacity may reveal the fact that by the use of a synchronous condenser he can secure some, if not all, of the following benefits:

1. Meet increased demands without the purchase of additional generating equipment—and by generating equipment is meant not only the generators but the necessary prime movers and auxiliary apparatus.
2. Reduce the cost per kilowatt of additional transmission rating.
3. Effect a material saving in present transmission losses.
4. Improve service by maintaining the required voltage.

Up to 1913 the Rankin plant, now rated at 10,000 kw., was operated independently of the rest of the system. At that time the load had grown to such an extent, owing chiefly to large individual motors and electric furnaces, that it became necessary to parallel with the main generating station at Brunot's Island, where the rating is 115,000 kw. This was done originally through two 11,000-volt lines. The central point of the load was then approximately midway between the two stations so that only about one-half of the line impedance came into the regulation problem, and it was possible to maintain fairly steady voltage at Rankin. During the last few years, however, the load grew so rapidly that it became necessary to deliver power direct to the Rankin bus for distribution. Two 22,000-volt lines were installed between the stations, having a combined capacity of 16,000 kva. The drop in these lines at full load is approximately

13 per cent. The problem which presented itself was how to obtain the best possible regulation in the 11,000-volt transmission network feeding from the Rankin bus, the load being approximately 10,000 kw. and the power factor ranging from 70 to 75 per cent. (The engine-type generators in the Rankin plant, which have been in service for a number of years, can be operated at low power factor only at reduced capacity.)

To accomplish the desired results at minimum expense, and at the same time provide for probable future increase in load, it was found, in view of the low power factor, that the installation of a synchronous condenser for corrective effect would actually reduce the transmission investment required per kilowatt, so that a condenser at this point was warranted on basis of transmission rating alone. A 7500-kva. unit was chosen which will permit operating the tie lines, when fully loaded, at a power factor of 90 per cent.

The particularly interesting feature in connection with the

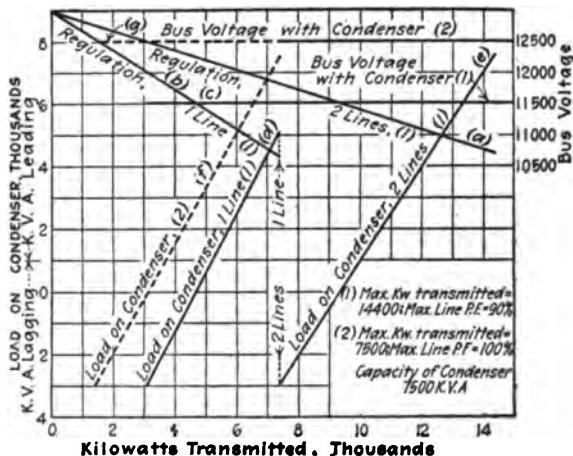


FIG. 91—LOAD AND REGULATION CURVES

present method of operation, made possible by the fact that the tie lines are not yet loaded to their rating and that the present load conditions do not require the full rating of the condenser at zero power factor, is the use of this machine as a voltage regulator. The Rankin plant is now run at practically full load with power factor of 90 to 95 per cent, and the voltage regulation of the station is taken care of entirely by an automatic regulator

controlling the condenser exciter, it being the only one in the plant. The regulation of the entire network, therefore, is affected automatically by the value of the magnetizing current drawn by the condenser.

The accompanying curves, Figs. 91 and 92, prepared from the transformer and line characteristics, will show the voltage compensation, or regulation, which can be obtained, the line amperes and line power factors, as follows:

- (a) Inherent regulation, two lines in parallel, 0 to 16,000 kva., 70 per cent power factor.
- (b) Inherent regulation, one line, 0 to 7750 kva., 70 per cent power factor.
- (c) Range of constant voltage obtainable when using synchronous condenser from maximum lagging kva. to maximum leading kva.
- (d) Synchronous condenser loads, one line in service.
- (e) Synchronous condenser loads, two lines in service.
- (f) Maximum load transmitted 7500 kw., both lines in service, maximum power factor 100 per cent.
- (g) Voltage range corresponding to curve (f).

There are several fixed adjustments which can be used to add to the voltage regulation as conditions materially change: (1) The ratio of transformers may be changed; (2) one line or two lines may be used; (3) the old 11,000-volt tie line having approximately 20 per cent regulation can be connected in on exceedingly light loads.

With one line in service and using maximum limits of condenser it will be noted from curves (c) and (d) that the voltage can be maintained constant with load varying from 3100 kw. to 7400 kw. Under load of 7400 kw. the maximum capacity of one line is reached, so at this point the second line is put in service, as shown by the arrows and dotted lines at curves (d) and (e). When the two lines are operated in parallel and using the condenser between its limits, constant voltage is obtained with load varying from 7400 kw. to 14,400 kw., as indicated by curves (c) and (e). With load of 14,400 kw. and condenser operating at maximum—90 per cent—and the lines are fully loaded at 16,000 kva. When the maximum load is only 7500 kva. and 100 per cent power factor is obtainable, it will be noted that flat voltage range

is materially increased, but since the allowable drop is reduced the transformer ratio must be changed.

While the curves show the limits of constant voltage with the condenser in service, it should be noted that it is very undesirable to run the machine at lagging power factor, since it reduces the power factor of the plant, which is already objectionably low. Upon referring to the power-factor curves, especially the one for one line, it will be seen how rapidly the power factor drops when the condenser is drawing lagging current.

While provided with a direct-connected exciter, which was also designed for use as a motor for bringing the machine up to synchronous speed, should this method of starting be desirable at any time, the condenser is self-starting and is equipped with an oil-pressure outfit for raising the shaft up from the bearings in order to eliminate the bearing friction and thereby reduce to a minimum the current required from the line, which otherwise would be comparatively large in amount at the instant of starting. With the oil-pressure outfit in operation the machine can be brought up to synchronous speed without drawing more than 1800 kva. to 2000 kva. from the line, as compared with 7000 kva. required when starting with the bearings dry. A pressure in

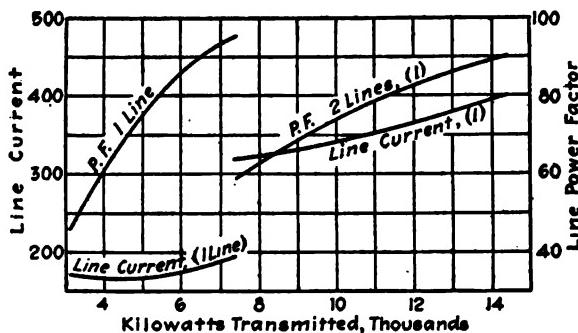


FIG. 92—LINE CURRENT AND POWER-FACTOR CURVES

the neighborhood of 100 lb. per sq. in. (7 kg. per sq. cm.) is required actually to lift the rotating part and provide an oil-bearing surface for the journal.

The equipment consists of a motor-driven duplex pump for each bearing and the necessary high-pressure piping. The cylinders are connected in pairs to a common pipe running to each

bearing, the oil returning to the pump chamber by an overflow pipe.

PREPARE HONOR ROLL FOR UNINTERRUPTED SERVICE

An honor roll is being compiled for those Doherty properties which give uninterrupted service. The names on the list are obtained from the weekly reports of the various properties, in which they state the number of interruptions to service during the week just past. Seven companies were on the honor roll for giving perfect service for the two weeks ended Dec. 10, 1918; i.e., the Cumberland & Westernport (Md.) Electric Railway Company, the Durham (N. C.) Traction Company, the Hattiesburg (Miss.) Traction Company, the Lincoln (Neb.) Gas & Electric Light Company, the Lorain County (Ohio) Electric Company, the Massillon (Ohio) Electric & Gas Company, and the Montgomery (Ala.) Light & Railway Company.

This information is sent to all of the properties in the organization and helps to promote competition in the matter of service. The same idea could undoubtedly be applied still further in some degree to district offices of electric light and power properties.

CLEARING HOUSE FOR IDLE STOCK

Realizing that it is difficult if not impossible to get new equipment under present conditions and desiring to keep down the investment in idle stock, some companies with electric service plants in various parts of the country have established clearing houses for idle stock regardless of whether it is new or used. Each plant is required to report its idle stock on hand periodically, this information being published in booklet form by the holding company and distributed among its plants. When any plant is in need of equipment included in this list it can communicate with the plant having the apparatus or material or with the holding company. Thus equipment can be obtained in a very short time compared with most manufacturers' deliveries nowadays. Furthermore, very much less reserve stock has to be carried.

SALESMAN'S ASSISTANCE IN SELECTING TRANSFORMER SIZES

The central stations are more conservative than formerly in making extensions, owing to their exorbitant cost, and many are asking the prospective consumer to pay a part of the expense. It is well known that the more money a "prospect" is asked to advance the harder it is to close the contract. It follows therefore that any information which the salesman can gather that will tend to decrease the expenditures will make it easier to do business, writes A. G. Drury.

The primary function of the construction department is to build and maintain the lines as economically as possible, and any assistance which the commercial man can lend in this work by his knowledge of the character of the power load to be added is likely to be appreciated by the superintendent.

One way in which to assist is in the selection of the size of transformers. It is evident that if at the end of the year the reports show that 2000 kw. connected load has been added to the system with 1000-kw. transformer capacity, it is better than adding 2000 kw. and 1500 kw. in transformers most of which are underloaded. The advantage exists not only in the amount of capital saved, but also in the amount of energizing current required by the smaller transformers as compared to the larger one.

As a concrete example there is related an incident which came up in connection with a contract for supplying electric energy to a company which made small brass and bronze casting cages such as are used in receivers' booths in banks, etc. The equipment which was to be driven by motors consisted of an elevator, a blower for gas furnaces, emery grinders, polishing machines, lathes, a milling machine, drill presses, etc., in all twenty-four such pieces of apparatus. The total number of motors to be installed amounted to 42 hp. The salesman had become familiar with the character of the work and reported that he had secured a 15-kw. maximum-demand contract. The manager accordingly ordered three 4-kw. transformers. One of the men in the office, knowing the motor equipment to total 42 hp., out of friendliness to the salesman told him that three 4-kw. transformers had been ordered, when there should have been three 10-kw. machines.

Upon inquiry it developed that the rule was for the salesman to report 40 hp. or 30 kw., upon which three 10-kw. transformers would be purchased, whereas with co-operation established between the two departments considerable saving in equipment would be accomplished.

The difference in first cost is as follows:

Cost to purchase and erect three 10-kw. transformers....	\$271.50
Cost to purchase and erect three 4-kw. transformers....	144.00
Saving in first cost.....	\$127.50

A test made on the installation mentioned after completion showed the maximum demand to be 12 kw.

The salesman by studying the characteristics of any new business can save as well as make money for his company. From considerable experience similar to the above Mr. Drury has found that the capacity of the transformers serving an installation can often be limited to less than a third of the connected load; but the salesman must make each individual investigation himself and not rely on the published tables of average load or maximum demands for different manufacturing businesses. The time and energy invested will be justified by the returns.

SAVING TIME IN VOUCHER FILING

The Agawam (Mass.) Electric Company and affiliated central stations, under the management of the Cabot interests of Boston, file vouchers most conveniently by making use of a method which is described in the following paragraphs:

Vouchers are properly classified under account numbers and are then kept in manila envelopes about 9 in. by 11½ in. (22.8 cm. by 29.2 cm.) in dimensions, the face of each envelope carrying all account titles and numbers, with space for amounts and totals under each class, as shown in Fig. 93.

Provision is also made for approval signatures, and a record of the check number paying the account and other information can be inscribed in the open spaces which are left on the envelope to serve the convenience of this office.

FIG. 93—FACE OF THE ENVELOPE FOR FILING VOUCHERS WHICH IS USED BY
A MASSACHUSETTS CENTRAL STATION

ECONOMY OF KEEPING RECORDS OF LABOR AND MATERIAL.

A scheme which encourages employees to economize time and material has been successfully developed by the Spokane (Wash.) Heat, Light & Power Company. The idea developed primarily in connection with construction work, but has been extended to include practically all operations where labor and materials are involved, even to firing boilers in the central heating plant.

The plan simply requires an advance estimate of the cost of any work to be done, and this estimate, embodied in a written work order, is given to the foreman or that employee who has the particular work in hand. Thus the work order becomes a bogie to the foreman and he endeavors to keep within it if he can. If he exceeds the figure set, he has to secure authorization for more expenditure, and his explanation of this situation brings out either (1) unforeseen conditions, which aid the estimating department in future work, or (2) evidence of waste which the foreman must clear up to the satisfaction of his superior.

The advantages claimed for the scheme are that, in addition to the actual money saving, the psychological effect is excellent. Foremen dislike to exceed estimates and be obliged to explain

why, and on the other hand they take pride in keeping the cost below the estimate. There are also the advantages of an accurate record of costs conveniently arranged, an allocation of all charges for labor, a constant check on materials on hand, and a means of making up the payroll easily at any time by totaling work-order records.

There are several forms about which the system centers. These begin with a letter size form known as the A. F. E. ("authority for expenditure"—Fig. 94), on which are entered the name of customer and a brief statement of the work to be done, with a list of the more important items that will be required on the work. It also states the amount which the work is estimated to cost. Before this A. F. E. sheet receives a work-order number and the work is classified it must be signed by officials of the sales department and the accounting departments, as well as by

FIG. 94—FORM USED TO EMBODY “AUTHORITY FOR EXPENDITURE” IN CENTRAL STATION OPERATION

the estimator and some one in a managerial position, either the general manager or the president. These A. F. E. sheets are made out in triplicate, one copy going to the superintendent, who

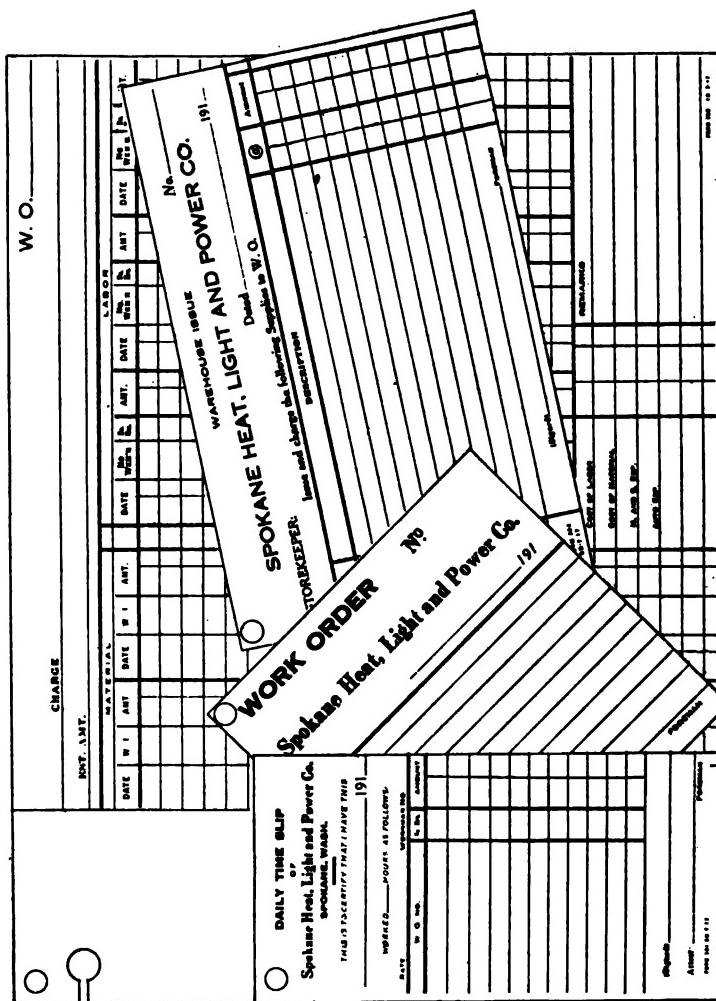
usually prepares the estimates, one copy to the engineering department and one to the accounting department. By using different colors the three forms are readily kept separate.

Next in order comes the work order (Fig. 96), a square 4-in. (10.16-cm.) slip, also made in triplicate, on which the most important entry is simply the work-order number. Of course, it also carries date and résumé of the work to be done. The copy of the work-order sent to the superintendent is on white paper and is simply his notification. It is not preserved or required again in the records. The yellow and blue copies, however, going to the accounting department and the foreman respectively are carefully kept, and by them the progress of the work is checked on the ledger sheet. This sheet (Fig. 97), which enters the scheme at this point, is a page from a loose-leaf file. It also bears the work-order number which identifies each individual job all through the records and carries the accounting department's detailed record of all materials and labor. It carries the figure which the work was estimated to cost, so that as the items of labor and material charges to the job increase their total can be compared with the estimate for the job. Thus the approach to the limit is readily seen and checked with the progress of the work.

As soon as the accounting department gets a yellow work-order slip, this is attached to a blank ledger sheet made out for the job, thus showing that it has been approved for construction. When the work is finished the blue work-order slip, duly signed by the foreman, is also attached. Thus a glance through the file shows what work is authorized and what is completed.

When a foreman requires materials he gets them from the warehouse by signing a small form called a warehouse slip (Fig. 98), on which the materials are itemized and which bears the work-order number. This is a notice of materials to be charged to a job and is sent to the accounting department and copied on the ledger sheet carrying the corresponding work-order number. Credit for materials returned from a job is later given on a similar slip and likewise listed on the ledger sheet.

One more form enters into the scheme. This is a small time slip (Fig. 95) filled out for every workman every day by his foreman. It bears the signature of workman and foreman and indicates the number of hours each man put in, the work-order number to which his work is to be charged and the total charge on



Figs. 95, 96, 97 AND 98—TIME SLIP, WORK ORDER, LEDGER SHEET AND WAREHOUSE SLIP USED BY PACIFIC COAST COMPANY TO SYSTEMATIZE OPERATION

each work order. The accounting department enters these data on the ledger sheet bearing the corresponding work-order number. Thus the system simplifies to the point that practically all data of permanent value are carried by the ledger sheet and a convenient means of completely checking the estimate, cost or progress of any job is thus afforded.

What are known as standing work orders are assigned to such work as firing boilers and any other plant maintenance work, so

that the daily reports can be simplified and yet keep the records standard for all kinds of work in which the company uses labor and material.

The system is a new feature, having been worked out in its present form only a few months ago, and minor changes have been made in it up to a recent date. However, company officials express great satisfaction in its effectiveness and point to notable reduction in construction costs since its adoption.

The system described in the preceding paragraphs has been worked out by Ludwig Kemper, president of the Spokane Heat, Light & Power Company, in conjunction with H. W. John, who is secretary-treasurer of the company.

USING MATERIAL CATALOGS FOR INVENTORY PURPOSES

In making inventories of overhead distribution systems difficulties are experienced in securing inspectors sufficiently familiar with line construction materials to list them correctly in detail. One company recently engaged in making a complete inventory for use in a rate hearing before a state public service commission provided its inspectors with illustrated catalogs showing in detail line hardware and appliances with appropriate names and style numbers.

A number of such sheets were provided, showing respectively cross-arms, bolts and braces, clamps, pins, brackets, anchors, strain insulators, grounding devices, cut-outs, lightning arresters, pin-type insulators, disconnecting switches, mast arms, lamp reels and hangers, time switches and dead-ends. The smaller devices were shown grouped in single photographs; the larger ones required separate sheets for each style.

It was found that photographs were cheaper to prepare than diagrammatic sketches, besides which they were more easily identified in the field. After the inventory was completed the booklets were found of service to inspectors checking completed work and to line foremen ordering material from the storeroom. Such a catalog will in fact be found useful for any central-station employee engaged in the purchase, handling or utilization of line materials.

SECTION VII

FEMALE LABOR

WOMAN SUBSTATION OPERATORS A NOTABLE SUCCESS

THE war brought a number of changes in central-station practice, but few of these are more significant than the use of women as substation operators on the system of the Boston (Mass.) Edison company. The Roslindale and Dorchester substations are now operated exclusively by women, and the results appear to be admirable in every way. The service appears to be fully as reliable as though men were in charge of these sub-stations. Emergencies have been skillfully met, and the effect upon the health of the operators has been uniformly good.

Early in 1918 C. H. Parker, superintendent of the generating department of the Boston company, foresaw that continued war demands would make it more and more difficult to retain and to replace male operators in the substations. The company distributes energy over an area of about 700 square miles, and for this reason the substation service is of great importance. Steps were therefore taken to secure applicants through the various suburban stores of the company, no advertising being required. To R. E. Dillon, assistant superintendent of the generating department, was given the task of interviewing the women who applied for substation work and passing upon their qualifications.

In general, fitness depends upon character, size, physique and kind of work previously performed. Electrical knowledge or experience is not an essential. It has been found that where a girl has been doing heavy machine work or farm tasks she is usually better fitted to take up operating duties than is one whose experience has been purely clerical. A good grade of intelligence is requisite, although it is not essential that the applicant shall have completed even a full grammar-school education.

Upon accepting eighteen applicants, the company organized a course of training for them at the laboratory in the Massachu-

sets Avenue Service Buildings, and here the class was instructed in the fundamental principles of electricity. The initial course included textbook study, practical demonstrations, equipment set-ups, visits to the main generating plant of the company at South Boston, trips to substations, lectures, black-board talks, examinations and reviews. The course was completed in a classroom partitioned off from the operating room at the Roslindale substation, the first large installation to be operated entirely by women in America. From the start of the work at the substation two students were detailed from the class daily to act as assistants to the male operators on shift. This gave them an insight into the routine work. Thorough instruction was given in the care and operation of rectifiers, transformers, regulators, oil switches and other equipment. Special study was given to the "general orders" of the company and to methods of meeting emergencies. On May 29 nine students went on watch at the Roslindale sub-

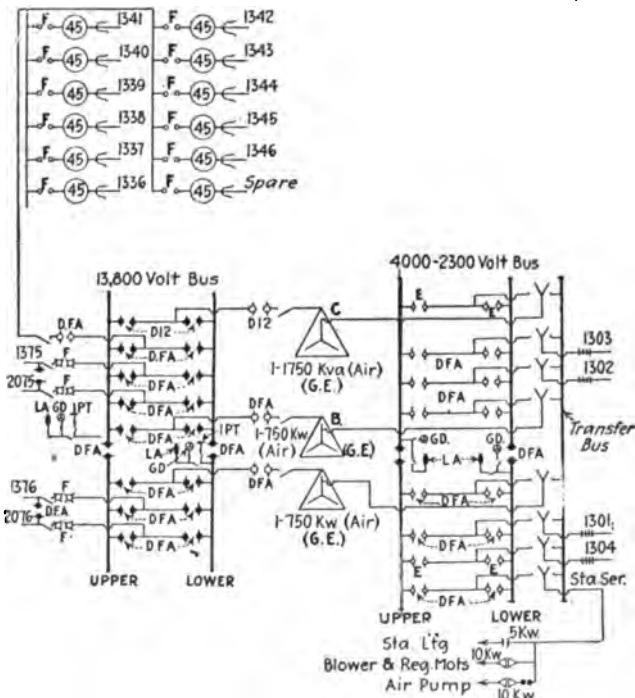


FIG. 90—ARRANGEMENT OF ROSLINDALE SUBSTATION

station, the male assistant operators being transferred to other stations, leaving only the operators, who were kept at Roslindale for the purpose of giving instruction in handling the substation routine. They were also given orders to act in a supervisory capacity and not to interfere except to prevent a serious error. On July 5 the remaining male operators were removed from the substation, leaving the women in entire charge. One of the former operators was retained to make repairs on apparatus and to act as an emergency operator, but the substation has been in the hands of women since the foregoing date. The original course has been shortened to about thirty days since the first class completed its work, and this is now the standard time for instruction.

The provision of separate lavatory facilities is the only change of importance required in the transfer of a substation from men to women operators, with the exception of extension handles for more easily setting oil switches.

This extension piece consists of a treated wooden handle about 18 in. (45.72 cm.) long and 1½ in. (38 mm.) square, fitted at one end and near the middle with two iron straps to engage the head and shank of the ordinary switch handle. The strap at the lower end is of ¼-in. (6.3-mm.) stock, 1 in. (25 mm.) wide and 3¾ in. (84.9 mm.) long, and is bored with two ½-in. (7.9-mm.) holes through which a pin 3 in. (75.4 mm.) long is carried when the extension piece is attached to the main handle. For some types of switch handles a wooden filler block is required at the lower end of the extension piece.

On July 17 the Dorchester substation was taken over by women operators. At this substation two members of a second class of applicants undergoing instruction were detailed to be "broken in" by the women operators. This work had previously been done by male operators, but was most satisfactorily accomplished under the new conditions.

The general arrangement of the Roslindale substation from the electrical point of view is shown in the accompanying single-line wiring diagram. The substation supplies energy for power, commercial and street lighting and has a rating of about 3790 kw. There are three banks of air-cooled transformers, two sets of 13,800 volt buses and a set of upper, lower and transfer buses for 4000/2300-volt service, besides an installation of 540

kw. in street-lighting transformer and rectifier equipment. The women operators are, of course, required to understand the detailed arrangement of all equipment in the substation, its handling and relations to the outside lines. The diagram symbolizes the daily work of the operators and is, of course, as familiar to them as to the men whom they succeeded.

The first class began its studies on March 25, and the first substation was completely taken over by women a little more than three months later. The revised course, as given by Mr. Wellington of the generating department, covers about a month. The women operators are paid the same wages as were the men and are also under compensation while studying. It is customary to take each class over to the South Boston station two or three times during the course in order that the general principles of electrical production may be set forth more effectively, the work of the load dispatcher seen, etc. The course is arranged to occupy six days per week, and a part of the work consists in meter reading by the entire class at substation switchboards as well as circuit tests required in routine operation.

The schedule of instruction is followed as closely as possible, but if occasions arise which necessitate a departure from the program, this is carefully noted for use in future courses. It is not the plan to hold the class to the exact minute in its curriculum, although the schedule has been planned on such a basis, to serve as a guide. Subjects in hand are carried out until completed. Every sixth day a review of previous work is held during the morning periods, and a written examination is held during the afternoon periods. The results of the examination then serve as a guide in the work of the following five days.

In general, the instruction starts each morning at 9 o'clock and a half-hour of meter reading follows. From 9:30 until 10:45 the class is then given either a talk or a demonstration, lasting until 10:45, upon the principles or practical application of equipment. A fifteen-minute recess is then followed by further in-

SYNOPSIS OF COURSE OF INSTRUCTION IN SCHOOL FOR FEMALE OPERATORS

Course to consist of three parts, parts of the course are combined as is follows:

- | | |
|---|--|
| Part I—Preliminary, progressive.
Part II—Theoretical, progressive.
Part III—Practical, non-progressive. Either two parts or all three | PART I—PRELIMINARY
I—ELECTRIC POWER.
(a) Definition. |
|---|--|

- (b) Journey of a pound of coal from coal mine to lamp socket.
- (c) What is to be found in a power plant.
- (d) What is to be found in a substation.

2—THE EDISON COMPANY—*Generating Department.*

- (a) Some statistics on number of stations, yearly output, daily output, daily maximum demand, classes of power generated and distributed, etc.
- (b) Kinds of stations: (1) Steam-engine stations, (2) steam-turbine stations, (3) motor-generator sub-stations, (4) transformer substations.
- (c) The generating department: (1) Personnel of department, (2) personnel of operating force, (3) duties of operating force.
- (d) Outline of work in substations: (1) Watches, (2) changes and days off, (3) vacations, sick benefits, etc., (4) notifications in case of absence for any cause.
- (e) Visits to stations: (1) Fourth station, (2) thirty-eighth station, (3) ninth station, (4) forty-third station.

3—ELECTRICAL APPARATUS.

- (a) Visit to stock room—nomenclature of apparatus.
- (b) Electrical terms—synonymous terms, definitions of various expressions in use.

PART II—THEORETICAL

1—ELECTRICITY.

- (a) Nature and analogy.
- (b) Static and current electricity.
- (c) Methods of producing electricity: (1) Mechanical, (2) chemical, (3) thermal.
- (d) Conditions necessary for current flow.
- (e) Properties of conductors and insulators—wire sizes, etc.
- (f) Effects of current flow: (1)

Magnetic, (2) thermal, (3) electrolytic.

(g) Ohm's law—units, ampere, volt and ohm..

(h) Resistance in series and parallel.

(i) Characteristics of series and parallel connections.

(j) Power: (1) Watt and kilowatt, (2) relation between electrical and mechanical power.

(k) Electrical diagrams: (1) Symbols, (2) one-line diagrams and others.

2—PRACTICE.

- (a) Methods of connecting apparatus: (1) Series, (2) parallel.
- (b) Methods of making: (1) Splices, (2) taps, (3) different types of connections to apparatus.

3—ELECTRICAL APPARATUS IN GENERAL.

- (a) All types of circuit breakers, switches, etc.
- (b) Incandescent lamps and accessories.
- (c) Fuses.
- (d) Bells and signals.
- (e) Wiring principles and practice: (1) Conduits, cleat work, etc.; (2) line wiring, overhead and underground; (3) high-tension wires and cables.

4—MAGNETISM.

- (a) Relation to electricity.
- (b) Laws of magnetism.
- (c) Electromagnets.

5—BATTERIES.

- (a) Types: (1) Dry cell, (2) wet cell.
- (b) Characteristics.
- (c) Uses and methods of connecting.
- (d) Storage batteries, elementary: (1) Characteristics, (2) application.
- (e) Why batteries are not used instead of generators.

6—METERS AND INSTRUMENTS, DIRECT-CURRENT.

- (a) Types.
- (b) Description of: (1) Amme-

- ter, (2) voltmeter, (3) wattmeter, recording.
- (c) Applications and connections.
- 7—PRINCIPLES OF INDUCTION.**
Lenz's law.
- 8—DIRECT-CURRENT APPARATUS.**
- (a) Dynamos, elementary: (1) Principles; (2) types—characteristics.
 - (b) Motors, elementary: (1) Principles, (2) types—characteristics.
 - (c) Operation of dynamos and motors.
- 9—ALTERNATING-CURRENT ELEMENTS.**
- (a) Description and analogy.
 - (b) Sine wave, elementary.
 - (c) Lead and lag.
 - (d) Impedance.
 - (e) Phase.
 - (f) Power factor.
 - (g) Alternating-current-circuits: (1) Single-phase, (2) polyphase, (3) transmission lines, (4) feeders.
 - (h) Alternating-current power.
 - (i) Alternating-current connections: (1) Delta, (2) "Y"—characteristics of each.
- 10—ALTERNATING-CURRENT APPARATUS.**
- (a) Alternators, elementary—theory and characteristics.
 - (b) Motors, elementary—theory and characteristics.
 - (c) Meters: (1) Ammeter, (2) voltmeter, (3) indicating wattmeter, (4) recording wattmeter.
 - (d) Transformers: (1) Theory; (2) applications; (3) Characteristics of power transformers, instrument transformers, and constant-current transformers; (4) Connections—delta and "Y."
- PART III—PRACTICAL**
- 1—APPARATUS IN STATIONS.**
- (a) Location.
 - (b) Diagrams.
- 2—OIL-BREAK SWITCHES.**
- (a) Theory.
- (b) Types: (1) Hand-operated, (2) remote-control.
- (c) Manipulation.
- 3—DISCONNECTING SWITCHES.**
- (a) Purpose.
 - (b) Manipulation.
- 4—RECTIFIERS.**
- (a) Theory.
 - (b) Theory of tubes.
 - (c) Constant-current transformers.
 - (d) Connections.
 - (e) Operation.
 - (f) Series circuit characteristics.
 - (g) Arc lamps, etc.
- 5—LIGHTNING ARRESTERS.**
- (a) Theory.
 - (b) Operation.
- 6—REGULATORS.**
- (a) Theory.
 - (b) Operation.
 - (c) Auxiliary apparatus: (1) Contact-making voltmeters, (2) linedrop compensators.
- 7—PROTECTIVE SYSTEMS.**
- (a) Methods of protecting apparatus.
 - (b) Methods of protecting lines and circuits: (1) Overload and time-limit protection, (2) balanced protection.
- 8—OPERATING, ELEMENTARY.**
- (a) Principles of operating—precautions, red tags, etc.
 - (b) Layout of buses.
 - (c) Transformers: (1) Starting up and shutting down, (2) air-cooling system in use.
 - (d) Station service panel.
 - (e) Arc-circuit test.
 - (f) Low-tension phase test and check.
 - (g) Testing of potential transformer fuses.
- 9—OPERATING, ADVANCED.**
- (a) Switching operations, 4000-volt board: (1) Changing over buses, (2) grounds, (3) short circuits, (4) live crosses, etc., (5) use of transfer bus.
 - (b) Switching operations, 13,800-volt board: (1) Loss of commercial line, (2) general switch-

- ing operations on order from load dispatcher.
- 10—MAINTENANCE.
- (a) Minor repairs.
 - (b) Station routine.
 - (c) Battery-charging, forty-third station.
 - (d) "General orders."
 - (e) Reading of meters.

struction or by observation and participation in substation test or switchboard handling until noon. Usually the half-hour from 1 P. M. on, after lunch, is given to informal discussion of matters arising in the course or noted in substation visits. From 2 to 5 P. M. intensive instruction continues, with a fifteen-minute recess beginning at 2:45 o'clock. In this period there may be a visit to another plant, perhaps accompanied by an hour of drawing by the class of wiring layouts, etc. From six and one-half to seven hours a day are given to instruction work. At the close of the course an allowance of about a week is made for necessary review work and final practice in switching operations, depending upon the fitness of the class members. The "general orders" of the company are given an increasing amount of study as the course progresses. A detailed schedule of the topics covered in the course is printed on preceding pages.

The operators wear a so-called "farmerette" uniform, selected by them at a Boston department store in response to the company's prohibition of skirts while on duty. This uniform fulfills the "safety first" requirement without completely sacrificing feminine taste.

The course of instruction occupies about 160 hours, divided as follows:

	Hours
Lectures and demonstrations	108
Visits to stations	15
Reading indicating and recording instruments.....	12
Visit to Edison company's stock room	4
Manipulation of oil switches (principle).....	1
Arc circuit test	3
Drawing diagrams of station apparatus and wiring layouts	11
Reviews and general discussions	6

SUBSTITUTING WOMEN FOR MEN

It seemed to be the general opinion of those who spoke in the discussion at the labor session of a recent convention of the Iowa Section, N. E. L. A., that it would be good policy to secure as early as possible the women who will be needed to take the place

of men to be called to the colors. Harold Boehmer of Malvern stated that he had had a woman reading meters for approximately two months and that he was well satisfied with her work. She is also delivering bills. He said she enters the homes more quickly than a man, causing less disturbance. The customers are better satisfied, as she reads the meters with greater accuracy and there is less re-reading to do than formerly.

M. G. Linn of Des Moines stated that his company was using some women as meter readers though still retaining a few men in the department to handle the meters which it would be difficult for the women to get to.

John M. Drabelle expressed the opinion that women could be employed successfully for meter testing and for calculating all power-house records.

A representative of the Lee Light & Power Company, Clarinda, said that the company was using women for collecting and for repairing on the customers' premises, as well as for handling all light supply work. The company had not then a single man in some of its small towns. The local manager is a woman. Arrangements have been made, however, for a man to go to each of these towns once a week. He climbs poles and does the heavy work that women are not physically able to do.

In another Iowa town it was reported that a woman is acting as local manager and has a male "trouble-shooter" under her direction. This combination is working out satisfactorily. All of the companies that were employing women expressed the belief that they were more honest as a rule than men.

COMPARISON OF WOMEN WITH MEN

W. A. Wadsworth, manager of the Kansas Gas & Electric Company, Wichita, Kan., speaking on the tendency of central-station companies to displace young men of the draft age with female employees, stated that in the experience of his company it takes about five intelligent women to replace four men on the ordinary sort of central-station routine work. It is figured that about one out of every twelve women will be absent every day. Moreover, the rate of turnover of labor is somewhat increased, so that it is necessary to keep a certain percentage of additional help to fill in gaps which are caused by positions being suddenly vacated.

The company had then twenty-five employees in its accounting department and all but three of these were women. Formerly the proportion of men and women in this department was reversed. The same thing prevails in the application department, which has about twelve employees. The company also expected to employ women as collectors, but did not believe it would be possible to use them for meter reading.

The experience indicates thus far that more women are required for the same work than men, but that female labor can be employed at a cost slightly less than that of male clerks. On the whole, therefore, the cost of operating a department remains about the same, as the one increased cost balances the other decreased cost.

SUCCESS WITH GIRL METER READERS

While there has been some hesitation about employing girls or women as meter readers owing to the inaccessibility of some meters and the condition in which cellars are frequently kept, some companies are finding the employment of women in this connection very satisfactory.

The Arkansas Valley Railway, Light & Power Company of Pueblo, Col., has for a very long time been employing young girls in the meter department as meter readers and has found them to be fully as competent and dependable as men in the number of meters read, and, according to Superintendent E. F. Stone, "if anything, more accurate."

Approximately 90 per cent of the meters in Pueblo are in the residence district, which enables girls to read a great percentage of the meters. The girls are limited to this district. The company employs one young man as a reader who handles the commercial and industrial districts and also acts as a relief reader.

The girls are furnished with a leather case in which to carry book and flashlight. They are also furnished with an identification card (Fig. 100). They receive the same compensation as the men formerly employed at this work. They are reading on an average twenty-five meters per hour, work from four to five hours in the morning and read "strays" or are employed in the shop in the afternoon cleaning and repairing meters.

By reading the meters in the morning and using the girls in

the shop in the afternoons the company finds the number of "strays" greatly reduced, as a greater percentage of the people are away from their residences in the afternoon.

When a girl is employed as a meter reader she is first required to serve at least a week or ten days in the shops cleaning and reading the shop meters. She must become efficient in reading shop meters before she is allowed to take a route.

The girls have met with little difficulty in obtaining admission to the homes to read meters. From comments that the

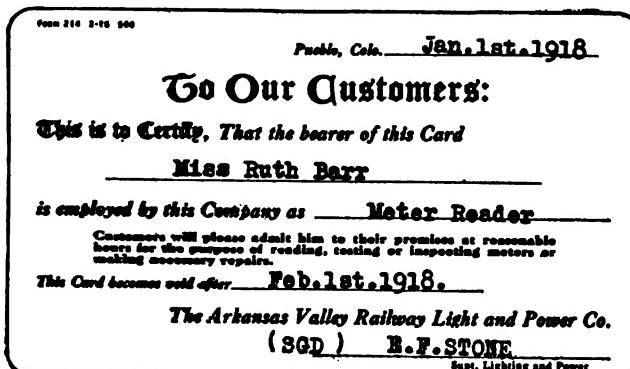


FIG. 100—IDENTIFICATION CARD OF GIRL METER READER

company has received from the housewives, they prefer to have girls read the meters, and the results attained make it very likely that the company will continue to use girls in this work.

WOMEN NOT ALLOWED TO TEST METERS IN PENNSYLVANIA

As a rule the class of men engaged in meter testing are those who by age, training and ambition have been attracted by the selective service feature of the draft, and as a result most companies find themselves faced with a shortage of men to carry on this work.

The Duquesne Light Company of Pittsburgh, Pa., was among the first to experience this depletion in the ranks of meter testers and, being unable to secure enough men over the draft age and reluctant to train mere youths for the work, it began to look about for women who seemed adapted to it.

Five girls were picked from a large number of applicants and their course of training started at the laboratory, of which C. W. Ward was the superintendent. Of these five, two were deemed especially fitted for the service tests and were trained with that disposition in view.

As this practice was a marked departure from past methods it was decided to tell the public about it. The route of these testers was to be determined in advance and the customers to be visited were to be advised by printed postal cards, to read as follows:

We are desirous of testing our electric meter installed at your premises in conformity with the requirements of the Public Service Commission of the state.

Owing to the shortage of skilled men occasioned by the war, we have, like many other concerns, been compelled to employ female help for work previously performed by males. We have, therefore, trained several women for meter testing, and one of these, Miss ——, will call at your place about the —— of —— for this purpose.

Will you kindly see that she is given admittance to our meter and any other courtesy that her work may require?

When all the details incident to the venture were about ready it was deemed advisable to secure the sanction of the Department of Labor and Industry of the state. An inquiry resulted in the call of an inspector from the department, before whom the plan was laid in detail, and as a result of this conference a letter, from which the following extracts are taken, was written to the Duquesne Light Company refusing permission:

At the last meeting of our Industrial Board it was ruled that in the opinion of the board the employment of women for the testing of electric meters would not be proper from a moral standpoint inasmuch as such work would lead them into out-of-the-way places.

This action is based on authority vested in the department as outlined in Section 14, Act No. 267, P. L. 1913, which reads as follows:

"All rooms, buildings and places in this commonwealth where labor is employed shall be so constructed, equipped and arranged, operated and conducted in all respects as to provide reasonable and adequate protection for the life, health, safety and morals of all persons employed therein. For the carrying into effect of this provision and the provisions of all the laws of this commonwealth the enforcement of which is now or shall hereinafter be intrusted to or imposed upon the

Commissioner of the Department of Labor and Industry, the Industrial Board shall have power to make, alter, amend and repeal general rules and regulations necessary for applying such provisions to specific conditions, and to prescribe means, methods and practices to carry into effect and enforce such provisions."

TRAINING WOMEN FOR METER READERS

Chiefly because the government had indicated that industries must help produce the needed additional military man power, the Commonwealth Edison Company of Chicago started to use women as meter readers. To train these new employees a temporary meter readers' school in charge of the foreman of meter readers has been opened. The equipment consists of chairs and tables, an exhibit of a number of meters and parts of meters, and a large model of a meter dial. This latter is used in meter reading practice, and examinations are held after the class has been thoroughly instructed by talks accompanied by demonstrations concerning the construction and working of meters.

Twenty or thirty changes are made on the large dial, each student marking down her record each time on a sheet of paper. These sheets are then collected and checked for accuracy. Three days is the usual duration of the school course, whereafter the graduates start out in their districts, accompanied by one experienced meter reader the first day to pilot them through the difficulties of practically applying the training they have received. Then each woman is given her own route and book of meter cards and is on her own responsibility. Only half routes are assigned at first. After about one week their work is usually good enough for strict supervision to be dispensed with.

To secure pupils for this school an advertisement was placed in one of the daily papers asking for mature women to learn meter reading. Those who were selected from the applicants are nearly all between thirty and forty years old. They came from many walks of life and include even some who have been trained nurses. Many of them are married.

During the selection of the applicants every attempt was made to explain fully the arduous character of the work, even to the point of attempting to discourage them. Further elimination occurred during the three days of schooling, about 30 per cent of the classes being dropped during this period. It is notable, how-

ever, that of the applicants who have satisfactorily finished their schooling only a small percentage have since found it necessary to drop out. This is in sharp contrast to the usual practice of young men who were formerly used, as 40 per cent of the male force was lost during August. While at this writing it was too early to draw decisive conclusions, it appeared that women will work out more satisfactorily than the class of male help available, being able to do as much work and being more accurate, principally on account of their greater sense of responsibility.

Neat leather handbags are given to the women in which to carry the meter seals, sealing tool, etc. They are wearing their usual street clothes for the time being, but something in the nature of a uniform suit will be adopted.

APPLIANCE REPAIRS CAN BE HANDLED BY WOMEN

Repairs on lamp cords, electric irons and other appliances are being made by a young woman maintainer with excellent results at the Head Place offices of the Boston (Mass.) Edison Company. This work was formerly done exclusively by men, but the inroads of the war led the company to try the experiment of utilizing feminine hands and eyes in getting such equipment into shape for use as quickly as it was possible to do so. This young woman had never had any previous mechanical or electrical experience prior to joining the staff of the Edison company early in 1918. She was employed for three weeks in filing requisitions in the company stock room at the General Service Buildings and was then given about a week's instruction in appliance repairing at the Head Place office. From Aug. 1 to Aug. 27 she effected 447 repairs on appliances, the maximum number per day being thirty-four. The hours are from 8:30 A. M. to 5 P. M., except on Saturdays, when the repair department closes at 1 P. M.

UNIFORMS FOR WOMEN EMPLOYEES

All women employees of the Kansas City (Mo.) Light & Power Company who meet the public on the company's first-floor office and salesroom are dressed in a standard uniform. The uniforms, which are neat but plain dresses, are made of cambric with poplin collars and cuffs. The total cost of material and making is \$3

per uniform. The company also provides free laundry service for these uniforms twice a week, which costs in addition 25 cents for each dress.

Uniforms were provided in order to prevent discrepancy in costume. Some of these girls have recently taken the places of young men. The company formerly employed boys in its lamp-renewal department, paying wages ranging from \$50 to \$60 a month. The boys were a source of continual trouble to the company, particularly because arguments were constantly arising between them and other youths whom customers of the company would send to the lamp-renewal department to transact their business.

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